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INTERCROPPING SUGARCANE WITH FOOD CROPS

M. A. Lugo-López, B. G. Capó, F. Aróstegui, and A. Riollano[1]

INTRODUCTION

Food production and supply have always been a matter of great importance to the inhabitants of Puerto Rico. More than half of the cereals consumed are imported. A great deal of the green and yellow vegetables and fruits are also imported, either as fresh or as canned products. Livestock products are also imported in large quantities for local consumption (4)[2]. In times of emergency, such as during World War II, food importations were reduced to critical levels. An increase in the total food produced in the Island would help substantially in assuring its food supply and in the amelioration of emergency shortages.

The Agricultural Experiment Station of the University of Puerto Rico has been engaged for a number of years in a program designed to increase the local production of food crops by making fertilizer and variety trials; by the introduction, selection, and breeding of food crops; and by seeking to devise improved soil- and crop-management techniques. The possibility of making a more intensive use of sugarcane lands by intercropping with food plants was given consideration during the past war emergency (1, 2, 3).

Generally speaking, the sugarcane plantings are located in the best lands of the Island. During the early stages (the first 2 or 3 months) of a sugarcane crop the slow germination and growth of the seedlings, especially from fall plantings, or ratoons provide an opportunity for using sugarcane lands more intensively by intercropping with food plants having a short growing period. Truck crops like tomatoes and cucumbers could be interplanted during the fall for shipping to continental United States during the winter season.

During World War II intercropping of sugarcane with beans, corn, cow-

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[2] Numbers in parentheses refer to Literature Cited, p. 182.

peas, soybeans, and other food crops was practiced to some extent by a considerable number of growers. The practice was then encouraged by the Agricultural Adjustment Administration (now Production and Marketing Administration) which required that some 20 percent of the productive farm area be in food crops in order to qualify for benefit payments. At present, the practice is virtually abandoned. Even at its peak, there seemed to be some reluctance among sugarcane growers to follow this practice, since claims were made that it yielded no profits. In fact, several growers and sugar companies reported heavy losses from intercropping.

The objective of the work herein reported was to provide information on the possibility of intercropping sugarcane with food crops, including crops suitable for the winter export market, under normal conditions. An effort was also made to determine which food crops are most suitable for intercropping with sugarcane. Incidental to the main objectives, a study was made of the best planting distances for sugarcane when interplanting with food crops.

EXPERIMENTAL PROCEDURE

Four field experiments were laid out, two at the Station's farm at Río Piedras in the north of the island, and two at the farm of the Isabela Substation in the northwest coastal area. The Río Piedras experiments were planted on a Vega Baja silty clay, a level alluvial soil, of the North humid coastal plains, normally requiring an extensive system of ditches to drain out excess waters. The plots were 33 feet long and 32 feet wide with a total area of 1,056 square feet, or 1/41.25 of an acre. Cane variety P.O.J. 2878, the most extensively grown in the Island, was planted both 4 feet and 8 feet apart, with 248 and 124 seedpieces per plot, respectively. There were eight furrows per plot at the 4-foot planting distance and four at the 8-foot planting distance. Cost accounts were kept for 3 crops at Río Piedras in terms of man-hours for all field operations performed on both the cane and food-plant crops.

Seminole soybeans and Mayorbela corn were interplanted with the plant cane in experiment No. 1, but native red beans were used instead of soybeans with the first ratoon crop. Cucumbers were used instead of corn in the second ratoon crop. For the second Río Piedras experiment, No. 3, native red beans and corn were interplanted with cane for the plant crop, while cucumbers were grown instead with the ratoon crop.

The Isabela experiments were planted on Coto clay, a rather friable, permeable, nearly level soil of the northwest coastal plains. One of the Isabela experiments, No. 2, was similar in design to the Río Piedras experiments except that sugarcane variety P.R. 903 was used instead of P.O.J. 2878. The following crops were interplanted with the plant cane of this

experiment: Cowpeas, cucumbers, melons, soybeans, and corn. In the first ratoon of this experiment the following crops were interplanted: Native red beans, corn, cucumber, native white beans, and tomatoes. The second ratoon crop of this cane had to be destroyed due to damage by white grubs.

In the second Isabela experiment, No. 4, sugarcane variety P.R. 902 was planted with 4-foot distance between rows and in $\frac{1}{70}$-acre plots. This plant cane was interplanted with native white beans, cucumbers, tomatoes, and melons, including check plots where sugarcane was grown alone. All treatments were replicated 12 times. In both Isabela experiments rainfall was supplemented with irrigation whenever necessary.

At all four experimental sites in both Río Piedras and Isabela, sugarcane was grown alone in plots randomized throughout the field. These were used as check plots in the statistical interpretation of the yield data. Each treatment was replicated 20, 15, 10, and 12 times at the Río Piedras, (experiments Nos. 1 and 3) and Isabela, (experiments Nos. 2 and 4), respectively.

The food crops interplanted with plant cane were set between each two sugarcane furrows; in ratoons they were planted only in the clean banks between sugarcane furrows. Two drills of seed were planted on each bank in the case of the legume crops. The cucurbits were planted on a single continuous drill in the center of each bank and were thinned out 10 days after germination. Corn was drilled along the banks in two rows with plants 2 feet apart in the row. Tomatoes were planted in rows with a 3-foot distance between plants. When cane was planted in rows 8 feet apart, there were twice as many food-crop plants as when it was planted only 4 feet apart.

The sugarcane plant crops received a 14-4-10 fertilizer at a rate of 1,000 pounds to the acre and a dressing of ammonium nitrate at a rate of 250 pounds to the acre. The ratoon crop received fertilizer at rates of 600 to 800 pounds to the acre, with dressings of ammonium nitrate ranging from 250 to 450 pounds to the acre.

The corn received a 10-10-5 fertilizer at a rate of 1,000 pounds to the acre. Cowpeas received 640 pounds to the acre of a 10-10-6 fertilizer. Other crops did not receive any special fertilizer applications, though they could share the fertilizer applied to the main crop.

Table 1 gives information as to planting and harvesting dates, age of cane at harvest, and rainfall during the growing period for the four crop cycles comprising the experiments. Eight sugarcane crops were harvested. The rainfall at Río Piedras was plentiful for both the sugarcane and food crops; however, at Isabela, supplemental irrigation was necessary to assure an adequate level of soil moisture during the growing period of the various crops.

The cane was harvested as in commercial practice. The cane from each

plot was weighed in the field by means of a portable crane and special weighing baskets. A sample of 10 canes was taken at random from each plot at harvesttime. The sample canes were then ground in the Station hydraulic mill at Río Piedras, and a juice sample was obtained for determination of the Brix and polarization values. The corn was all harvested at once, but the harvest of the other food crops was spread over a period of time. Legumes were picked at three different times during a 15-day period; cucurbits and tomatoes at various times for a short interval. In the second Isabela experiment, No. 4, cucumbers were harvested after the

TABLE 1.—*Location, crop cycles, planting and harvesting dates, age at harvest, and rainfall during the growing period for 4 intercropping experiments with sugarcane at Río Piedras and Isabela*

Location	Experiment No.	Crop	Date of planting	Date of harvest	Crop age	Rainfall during growing period
					Months	*Inches*
Río Piedras	1	Plant cane	May 10–11, 1944	Apr. 23–26, 1945	11½	67.7
		First ratoon		Mar. 21, 1946	11	60.0
		Second ratoon		Mar. 17–21, 1947	12	74.6
Isabela	2	Plant cane	May 10, 1944	Apr. 2–4, 1945	11	52.0
		First ratoon		Mar. 18, 1946	11	53.7
Río Piedras	3	Plant cane	Dec. 26–28, 1944	Feb. 11–14, 1946	13½	71.0
		First ratoon		Mar. 24–29, 1947	13	78.4
Isabela	4	Plant cane	Mar. 6–11, 1946	Mar. 17, 1947	11	52.0

fruits were mature as is done in seed production. The yields of food crops were weighed in the field. Statistical analyses were made of the yield data in terms of sugar produced per acre and also of the cost accounts data.

RESULTS

Table 2 shows the mean sugar production of a plant cane and two ratoon crops in the intercropping experiment at Río Piedras for the period 1944–47. Cost accounts are also given for the first two crops in the cycle.

As shown in Table 2, planting sugarcane with 4 feet between rows led to significantly higher available sugar yields than planting with 8 feet between rows, whether the cane was grown alone or intercropped with any one of the various food crops. (This is further corroborated by the data in tables

TABLE 2.—*Yields of and profits or losses on a plant cane and 2 ratoon crops in intercropping experiment No. 1, Río Piedras, 1944–47*

Treatment letter	Description of experiment No. 1				Available 96° sugar yields from—			Mean profit or loss per A. for[1]—	
	Crop interplanted with sugarcane in—			Distance between sugarcane rows	Plant crop	First ratoon	Second ratoon	Plant crop	First ratoon
	Plant crop	First ratoon	Second ratoon						
				Feet	*Cwt./A.*	*Cwt./A.*	*Cwt./A.*		
A1	None	None	None	4	65.7	73.8	113.5	$-52.2	$73.9
A2	do.	do.	do.	8	46.8	57.4	93.5	−65.6	30.8
B1	Soybeans	Native red beans	Native red beans	4	64.9	68.7	109.2	−44.3	24.2
B2	do.	do.	do.	8	42.6	53.1	94.7	−61.9	−17.0
C1	Corn	Corn	Cucumbers	4	54.1	65.4	109.2	−63.7	19.8
C2	do.	do.	do.	8	39.1	47.0	93.6	−69.9	−8.7
L. S. D. at the 5-percent level					5.2	5.7	6.2	13.2	17.0
L. S. D. at the 1-percent level					6.9	7.6	8.2	17.5	22.6

[1] Computed on the basis of 65 percent of the total sugar produced, the farm value of the food crops, and including all expenses in labor, fertilizer, and other materials.

TABLE 3.—*Mean sugar yields of 2 cane crops interplanted with food crops in intercropping experiment No. 2, Isabela, 1944–46*

Treatment letter	Description of experiment No. 2			Available 96° sugar yields for—	
	Crop interplanted with—		Distance between sugarcane rows	Plant cane	First ratoon crop
	Plant cane	First ratoon crop			
			Feet	*Cwt./A.*	*Cwt./A.*
A1	None	None	4	69.5	55.4
A2	do.	do.	8	51.1	43.1
B1	Soybeans	Native red beans	4	39.0	50.8
B2	do.	do.	8	40.8	32.3
C1	Corn	Corn	4	25.1	47.6
C2	do.	do.	8	33.5	29.2
D1	Cucumbers	Cucumbers	4	78.0	62.7
D2	do.	do.	8	52.4	45.7
E1	Cowpeas	Native white beans	4	65.3	59.5
E2	do.	do.	8	53.6	38.5
F1	Melons	Tomatoes	4	74.8	66.9
F2	do.	do.	8	54.5	47.9
L. S. D. at the 5-percent level				10.2	9.7
L. S. D. at the 1-percent level				13.6	12.8

3 and 4). Intercropping plant cane with the Seminole variety of soybeans had no significant effect on the available sugar yields. This conclusion is based on the respective comparisons of the sugar yields of treatments B1

TABLE 4.—*Mean sugar yields of 2 cane crops, and profits on the plant cane, when interplanted with food crops in intercropping experiment No. 3, at Río Piedras, 1944–47*

Treatment letter	Description of experiment No. 3			Available 96° sugar yields in—		Mean profits per acre for plant cane[1]
	Crop interplanted with—		Distance between sugarcane rows	Plant crop	First ratoon crop	
	Plant Crop	First ratoon crop				
			Feet	*Cwt./A.*	*Cwt./A.*	
A1	None	None	4	119.2	122.3	$151.9
A2	do.	do.	8	96.5	107.5	95.9
B1	Native red beans	Native red beans	4	118.2	135.2	206.6
B2	do.	do.	8	91.2	107.1	135.7
C1	Mayorbela corn	Cucumbers	4	108.4	139.1	139.7
C2	do.	do.	8	78.3	111.6	64.5
L. S. D. at the 5-percent level				9.0	9.3	24.4
L. S. D. at the 1-percent level				11.9	12.3	32.4

[1] Computed on the basis of 65 percent of the total sugar produced, the farm value of the food crops, and including all expenses in labor, fertilizer, and other materials.

TABLE 5.—*Mean sugar yields of a P.R. 902 plant-cane crop interplanted with food crops in intercropping experiment No. 4, Isabela, 1946–47*

Treatment letter	Crop interplanted with sugarcane	Distance between sugarcane rows	Available 96° sugar yields
		Feet	*Cwt./A.*
A	None	4	105
B	Native white beans	4	98
C	Cucumbers	4	99
D	Tomatoes	4	102
E	Melons	4	109
L. S. D. at the 5-percent level			12.6
L. S. D. at the 1-percent level			16.8

and B 2 with those of treatments A1 and A2. This lack of significance is further corroborated by the fact that there were no significant differences between the mean excess of expenditures over income for the corresponding treatments. Table 2 further shows that intercropping Mayorbela corn with sugarcane had a detrimental effect on sugar production when planting-distance effects are disregarded.

The intercropping of native red beans with sugarcane had no appreciable effect on sugar yields in the first ratoon crop, but intercropping with corn markedly reduced them. In the second ratoon crop, intercropping with

TABLE 6.—*Analysis of variance of the yield data obtained in 3 intercropping experiments at Río Piedras and Isabela, 1944–47*

Source of variation	Degrees of freedom	Sum of squares	Variance estimate	*f*
Río Piedras Experiment No. 1—plant cane				
Total	119	31,472		
Blocks	19	11,201		
Distance	1	10,435	10,435	83.48[1]
Error (a)	19	2,381	125	
Intercropping	2	1,943	971	14.11[1]
Intercropping × distance	2	278	139	2.02
Error (b)	76	5,234	69	
Río Piedras experiment No. 1—first ratoon				
Total	119	26,764		
Blocks	19	8,219		
Distance	1	8,484	8,484	80.36[1]
Error (a)	19	2,006	105	
Intercropping	2	1,796	898	10.98[1]
Intercropping × distance	2	41	20	.25
Error (b)	76	6,218	82	
Río Piedras experiment No. 1—second ratoon				
Total	119	27,110		
Blocks	19	8,820		
Distance	1	8,333	8,333	66.19[1]
Error (a)	19	2,392	126	
Intercropping	2	99	49	.52
Intercropping × distance	2	167	18	.19
Error (b)	76	7,299	96	
Isabela experiment No. 2—plant cane				
Total	116	48,268		
Blocks	9	5,806		
Distance	1	3,608	3,608	53.06[1]
Error (a)	9	616	68	
Intercropping	5	22,253	4,450	33.64[1]
Intercropping × distance	5	4,476	895	6.77[1]
Error (b)	87	11,509	132	

TABLE 6—*Continued*

Source of variation	Degree of freedom	Sum of squares	Variance estimate	
Isabela experiment No. 2—first ratoon				
Total	116	32,301		
Blocks	9	6,939		
Distance	1	9,399	9,399	128.75[1]
Error (a)	9	661	73	
Intercropping	5	5,252	1,050	9.29[1]
Intercropping × distance	5	216	43	.38
Error (b)	87	9,834	113	
Río Piedras experiment No. 3[2]—plant cane				
Total	88	35,555		
Blocks	14	5,364		
Intercropping	2	3,505	1,752	11.46[1]
Distances	1	15,920	15,920	104.07[1]
Intercropping × distance	2	211	105	.69
Error	69	10,555	153	

[1] Significant at the 1-percent level.
[2] Statistical data missing for ratoon crop.

native red beans and cucumbers produced no significant reduction in sugar yields.

The mean sugar yields of two cane crops interplanted with food crops in a field of Coto clay at Isabela (experiment No. 2) are shown in table 3. The results with the plant cane indicate that intercropping with soybeans or corn led to significant reductions in sugar yields at both planting distances, while intercropping with cucumbers, cowpeas, or melons had no effect on the sugar yields at either planting distance. The soybean crop was almost a complete failure because of a very severe insect attack. The melons were a complete failure. They were planted rather late and growth was slow, the partial shade of the young cane plants being very detrimental to their development.

Cucumbers, native white beans, and tomatoes interplanted with sugarcane ratoons had no significant effects on yields. In both the plant and ratoon crops the planting of corn between sugarcane rows resulted in lowered sugar yields.

Table 4 gives data on sugar yields of two crops grown at Río Piedras during the period 1944–47. In the plant crop, sugarcane was intercropped with native red beans and Mayorbela corn, while cucumbers instead of

corn were grown with the ratoon crop. Native red beans and cucumbers had no effect on the sugar yields, but corn reduced them.

Table 5 shows the results of the second Isabela experiment, No. 4. The yields of sugarcane were not affected by intercropping with native white beans, cucumbers, tomatoes, or melons. All the food crops were harvested successfully, except the melons. They could not keep pace with the rapid growth of the spring-planted cane seedlings.

TABLE 7.—*Yields of food crops interplanted with sugarcane in 4 experiments at the Isabela Substation and at the Río Piedras Main Station, 1944–45*

Crop No.	Crop[1]	Cane planting distance	Mean yields
		Feet	*Cwt./A.*
1	Cowpeas	4	3.3
2	do.	8	2.7
3	Soybeans	4	2.7
4	do.	8	3.2
5	Native white beans	4	3.6
6	do.	8	3.5
7	Native red beans	4	1.6
8	do.	8	2.0
9	Corn	4	22.4
10	do.	8	18.3
11	do.	4	12.0
12	do.	8	11.4
13	Cucumbers	4	16.1
14	do.	8	31.2
15	do.	4	40.4[2]
16	do.	8	21.1[2]
17	Tomatoes	4	16.1
18	do.	8	22.1

[1] Corn crops 11 and 12 were produced at Río Piedras, all others at Isabela.

[2] Harvested after fruits were mature, as used in seed production.

Data on the sum of squared deviations of the yields obtained in the various intercropping experiments conducted at both Río Piedras and Isabela, except for the ratoon of crop experiment No. 3, and the plant crop of experiment No. 4, are given in table 6.

Data on the mean yields of some food crops interplanted with sugarcane are presented in table 7. All yields were satisfactory considering the conditions under which the crops were grown. Corn, cowpea, native white bean, native red bean, tomato, and soybean yields did not seem to be affected by the planting distance of the sugarcane. However, P.R. 39 variety of cucumbers produced nearly 50 percent more fruits when the cane furrows were 8 feet apart than when they were only 4 feet apart.

DISCUSSION

An over-all examination of the data obtained from seven crops in three experiments indicates that a planting distance of 4 feet between rows of cane is much better from the standpoint of sugar yields than one of 8 feet. regardless of whether or not the cane is intercropped with these or some other food crops similar to those tested.

The experimental evidence further indicates that it is possible to intercrop cane with some food crops without affecting the sugar yields. It also shows that some crops like cucumbers, tomatoes, and melons, can be interplanted satisfactorily during the fall season with a possibility of shipping the produce to Continental United States during the winter season. These observations suggest the possibility of increasing the efficiency of utilizing sugarcane lands. This is of extreme importance in view of the limited amount of good arable land available in Puerto Rico for food-crop production. Furthermore, the sugarcane plantings are generally located on the more level and more fertile soils of the Island, where mechanization in field operations is practicable.

Legume crops, such as soybeans, native red beans, native white beans, and cowpeas, can be grown to advantage when intercropped with sugarcane. Field observations indicate that the soybeans and other legume crops do much better when grown in association with a plant cane than with a ratoon crop; this is true from the standpoint of both crops. It seems that the competition for nutrients and space is much stiffer with ratoon crops having well-established root systems than with young cane seedlings. The trash residues left after harvesting the sugarcane crops considerably reduces the planting area for the food crop.

Tomatoes and cucumbers, can also be grown profitably in association with a sugarcane crop. Melons could perhaps be intercropped to advantage, if planted early in the fall. However, it seems that melons are not suitable for intercropping in spring plantings because sugarcane grows more rapidly and the melon crop takes a rather long period of development. In general, crops which do not attain much height combine rather nicely with young sugarcane plants. Tall field crops of the grass family such as corn are not suitable for growing in association with young sugarcane plants. The results available from the five experiments in which corn was included consistently show a reduction in available 96° sugar yields from fields where corn was interplanted with sugarcane, as compared with no effects, or even beneficial effects, from interplanting sugarcane with legumes, tomatoes, cucumbers, and similar food crops.

The rather harmful effects of the association of corn plants with young cane may perhaps be caused by the heavy nutrient extraction from the soil by the rapidly growing corn plants, especially at the early critical stages

of cane growth. This competition for nutrients is probably more acute for nitrogen which is usually demanded in relatively large quantities by plants of the grass family such as sugarcane and corn. Moreover, field observations indicate that field mice are attracted by corn plantings and remain in the cane fields after the corn is harvested, doing great damage to the sugarcane crop.

The possibility of using the same land area for the production of a normal crop of sugarcane and another of food crops, other than corn, has no economic disadvantages. In some of the cases studied during the course of the experiments herein reported, significantly higher returns per acre were obtained when interplanting sugarcane with food crops than when planting sugarcane alone.

In a program geared to the most intensive utilization of the land as a means of increasing the agricultural output of the Island careful consideration should be given to the production of food crops in the sugarcane-producing areas. In this respect, the evidence reported here is rather encouraging and should receive careful consideration from growers and Government agencies alike.

SUMMARY

Data are presented here for two intercropping experiments, involving five sugarcane crops, conducted in an imperfectly drained alluvial soil at Río Piedras on the north coast, and for two intercropping experiments (three sugarcane crops) conducted at Isabela on a level lateritic soil of the northwest coastal plains. At both locations sugarcane was planted in rows 4 feet apart and 8 feet apart. Sugarcane was grown alone and intercropped with either soybeans, corn, native red beans, native white beans, cucumbers, cowpeas, melons, or tomatoes.

Statistical analysis of the results obtained indicate that, at a planting distance of 4 feet between rows of cane, higher sugar yields can be obtained than at an 8-foot planting distance, regardless of whether the cane is grown alone or intercropped. Legume crops such as soybeans, native red beans, native white beans, and cowpeas, can be grown advantageously with sugarcane. Cucumbers, melons, and tomatoes also can be grown in association with the young cane plants without reducing the sugar yields. Corn, however, is detrimental to the production of sugar when grown in association with the young cane plants. Such intercropping of sugarcane soils is feasible technically and economically and should receive careful consideration as a means of increasing Island food production on the same acreage.

RESUMEN

Se presentan aquí los datos de dos experimentos de campo, que incluyen cinco cosechas de caña, y los cuales fueron sembrados en un suelo de alu-

vión con desagüe imperfecto en Río Piedras, costa norte de Puerto Rico, y de dos experimentos con tres cosechas de caña en un suelo laterítico de la zona de Isabela, en las llanuras costaneras del noroeste. En ambos sitios, la caña se sembró en hileras a 4 y a 8 pies de distancia. En algunas parcelas la caña se sembró sola y en otras se intercaló con otros cultivos, tales como habichuelas soyas, habichuelas coloradas del país, habichuelas blancas del país, pepinillos, fríjoles, melones y tomates.

El estudio estadístico de los datos obtenidos revela que la caña sembrada en hileras a 4 pies de distancia rinde más azúcar que la que se siembra a 8 pies, no importa que esté sola o intercalada con otras cosechas. Las plantas leguminosas, tales como las soyas, fríjoles, habichuelas coloradas y habichuelas blancas del país pueden intercalarse ventajosamente con la caña. Los pepinillos, melones y tomates, también pueden sembrarse en asociación con las plantas jóvenes de caña sin temor a que ocurra una reducción en la producción del azúcar. El maíz, intercalado con la caña, no es recomendable, pues reduce la producción de azúcar de la caña. Tanto técnica como económicamente es posible usar los suelos que se dedican a la caña con cultivos intercalados, práctica esta que debería recibir mayor consideración como uno de los medios para aumentar la producción de alimentos en la Isla sin tener que utilizar terrenos adicionales.

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POTASSIUM CONTENT OF PUERTO RICAN SOILS AS RELATED TO SUGARCANE GROWING[1]

By Juan A. Bonnet[2]

INTRODUCTION

Potassium may occur in soils in one or more of the following forms: As a constituent of some primary minerals such as feldspars and micas; associated with a secondary clay mineral as exchangeable potassium; as nonexchangeable potassium, such as within the clay-mineral lattice; and as water-soluble potassium salts.

The primary potassium-bearing minerals that may be found in soils are orthoclase, a potash feldspar, $KAlSi_3O_8$; microline, resembling orthoclase but differing in molecular structure and in optical characteristics; muscovite, a fairly stable mica, $KH_2Al_3Si_3O_{12}$; glauconite, a green granular silicate of potassium and iron closely related to the micas; and biotite, a potassium-magnesium-iron-aluminum silicate, a mica not very resistant to decomposition.

Sericite, or secondary muscovite, a compact or fibrous mica-bearing potassium derived by the conversion or sericitization, of orthoclase feldspar, is also found in some soils.

The potassium in the feldspars and mica minerals is distributed in the coarser sand and silt fractions of the soil.

The range of potassium content varies from about 0.15 percent K_2O in sands to over 4 percent in clays. The clay mineral has the power to fix the potassium cation from the soluble salts in the run-off and drainage waters.

When soluble potash salts are applied to soils, the potassium may be retained in either or both of two forms; namely, the readily available or exchangeable form and the difficultly available or fixed form. The nature of potash fixation have been studied by several investigators and different explanations have been offered. Volk (9)[3] has suggested that K is fixed by muscovite or reacts with silicates to form difficultly soluble muscovite. Truog and Jones (8) have found that alternate wetting and drying hasten the fixation of potassium.

Stewart and Volk (7) said that the variable capacity of different soils to release potassium from the nonexchangeable form for plant consumption

[1] Paper prepared for the Eighth Congress of the International Society of Sugarcane Technologists at Barbados, B.W.I., in April 1953.

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[3] Numbers in parentheses refer to Literature Cited pp. 193–4.

appeared to be a dominant factor in the nutrition of plants, and that the magnitude of this factor was difficult to measure with chemical soil tests.

Potassium fertilizers are currently used at excess levels in the sugarcane fields of Puerto Rico. There are no potash deposits here and high-priced potash bearing materials are imported. A total of 43,971 tons of potash fertilizer salts[4] at a total cost of $2,863,126 was imported in fiscal year 1951–52. The N-P-K fertilizer formulae sold for sugarcane in Puerto Rico vary from 5 to 20 percent of K_2O and potash is applied at rates varying from 70 to 216 pounds K_2O to the acre. It is estimated that about $600,000 is wasted annually on potash fertilizers applied excessively to sugarcane fields in Puerto Rico.

OBJECTIVE

The objective of this paper is to present data which show that chemical methods are not always reliable when used to determine the potash that plants absorb from the soil.

FINDINGS

Potash-Bearing Minerals of Puerto Rico Soils

Muscovite, a mica primary mineral bearing potassium, was identified (1) in the specific gravity groups: Greater than 2.98, 2.70–2.98, 2.50–2.70, and less than 2.50, of the silt fraction of Catalina clay, a Low Humic Latosol from Puerto Rico. Muscovite was relatively scarce in the first two specific gravity groups, abundant in the third, and present in traces in the last. Small quantities of sericite, a secondary muscovite, were found in the specific gravity group, 2.70–2.98. The primary orthoclase feldspar was absent.

Jeffries, Bonnet, and Abruña (4) reported the absence of micas, especially the common muscovite, in 42 soil profiles, including 118 soil samples of Puerto Rico studied. Traces only of orthoclase were found in the alluvial soils of the Coloso series in the humid area, and in the Juncos and Las Piedras series of the Gray Brown Podzolic group. The principal feldspars identified were those of the plagioclase series: Oligoclase, andesine, and traces of labradorite, all containing sodium and calcium in varying proportions.

Potash Data on Puerto Rico Soils

The data on total potash in Puerto Rico soils are limited to those published in the Soil Survey of Puerto Rico (5) for eight soil profiles including five Latosols and two Gray-Brown Podzolic soils reported in table 1.

[4] 40,795 tons of muriate of potash and 3,176 tons of sulfate of potash at $64.50 and $73.00 per ton, respectively.

Bonnet (2) has reported that the mean available potash extracted by 1-percent citric acid from the surface soils of the soil series of the humid

TABLE 1.—*Total potash in 8 soil profiles of the Puerto Rico humid area*

Soil Group	Soil series	Horizon	Depth	Total K_2O	K_2O per acre
			Inches	*Percent*	*Pounds*
Reddish Brown Lateritic	Catalina	A	0–18	0.08	1,600
		B	18–28	.01	200
		C1	28–68	.91	18,200
		C2	68–88	.84	16,800
		C3	88–125	.75	15,000
Do.	Cialitos	A1	0–6	.06	1,200
		A2	6–12	.15	3,000
		B1	12–24	.20	4,000
		B2	24–36	.16	3,200
		C	36–48	[1]	—
Yellowish Brown Lateritic	Coto	A1	0–7	.18	3,600
		B1	7–17	.15	3,000
		B2	17–40	.23	4,600
		C	40–70	.19	3,800
Do.	Matanzas	A1	0–12	.23	4,600
		B1	12–21	.16	3,200
		B2	21–34	.23	4,600
		C1	34–68	.21	4,200
		C2	68+	.21	4,200
Do.	Nipe	A	0–5	0.9	1,800
		B1	5–15	.02	400
		B2	15–50	[1]	—
		C1	60	[1]	—
		C2	144	[1]	—
Gray Brown Podzolic	Fajardo	A	0–6	.18	3,600
		B1	6–12	.42	8,400
		B2	12–28	.49	9,800
		C	28–50	.60	12,000
Do.	Yunes[2]	A	0–6	.11	2,200
		B	6–9	.17	3,400
		C	9–30	.15	3,000
Do.	do.[3]	A	0–4	.65	13,000
		B	4–14	.42	8,400
		C	14–28	.62	12,400

[1] Trace.
[2] Clay.
[3] Silt loam.

area of Puerto Rico was 0.020 ± 0.0015 percent of K_2O. That of the arid area, with a mean annual rainfall below 55 inches, was 0.023 ± 0.0017 percent of K_2O. There was no significant difference between those mean

TABLE 2.—*Exchangeable potash extracted with 1-percent citric acid from samples in certain soil groups of Puerto Rico*

Sample No.	Soil group	Range of K_2O per acre	Mean K_2O per acre
		Pounds	*Pounds*
6	Ground Water Podzol	100–420	240
31	Reddish Brown Lateritic	80–620	300
10	Yellowish Brown Lateritic	100–1,060	340
24	Gray Brown Podzolic	80–760	340
62	Alluvial	120–1,600	340
18	Lithosols	60–1,300	360
32	Reddish Prairie	120–1,060	400
13	Chernozem	180–760	400
14	Planosol	100–1,140	440
22	Red and Yellow Podzolic	100–1,080	440
14	Rendzina	100–1,200	440
19	Sands	100–1,260	440
10	Reddish Chestnut	120–1,040	460
4	Red Desert	120–980	560
8	Reddish Brown	340–1,060	600
6	Solonchak	280–1,240	660
11	Wiesenboden	120–1,920	680
4	Half-Bog	220–1,620	860

TABLE 3.—*Available potash extracted by sorghum in pot tests from certain Puerto Rico soil groups*

Sample No.	Soil group	Range of K_2O per acre	Mean K_2O per acre
		Pounds	*Pounds*
1	Sands	122	122
2	Planosol	204–344	274
7	Red and Yellow Podzolic	234–598	408
12	Alluvial	158–547–1,572[1]	415
1	Yellowish Brown Lateritic	421	421
7	Reddish Brown Lateritic	276–884	423
2	Bog	360–640	500
7	Reddish Prairie	328–1,017	546
6	Gray Brown Podzolic	314–939	678
1	Half-Bog	684	684
1	Reddish Chestnut	714	714
4	Lithosols	125–2,961	1,019
3	Rendzina	520–1,727	1,050
1	Chernozem	1,496	1,496
1	Reddish Brown	2,054	2,054

[1] San Antón loam in the arid irrigated area.

values. There was a significant positive correlation in the soil series of the humid area between the available potash and the organic matter of those

TABLE 4.—*Mean available potash extracted by sorghum and by 1-percent citric acid from some Puerto Rican soil groups and series in which feldspars were present and clay minerals were identified*

Soil group	Soil series	K_2O per acre extracted by—		Clay mineral
		Sorghum	1-percent citric acid	
		Pounds	*Pounds*	
Gray Brown Podzolic	Ciales	939	280	Kaolin, illite
Do.	Humacao	—	420	Kaolin
Do.	Juncos[1]	820	200	Montmorillonite, kaolin
Do.	Las Piedras[1]	—	120	Kaolin, beidellite
Do.	Teja	—	500	Kaolin
Do.	Utuado	697	260	Do.
Reddish Brown Lateritic	Alonso	436	380	Do.
Reddish Prairie	Mabí	449, 1,017,505	400	Kaolin, illite, Beidellite
Do.	Paso Seco	542	660	Kaolin, illite
Reddish Chestnut	Fraternidad	—	280	Beidellite (carbonates)
Reddish Brown	Jácana	2,054	420	—
Planosol	Santa Isabel	—	700	Kaolin-illite
Wiesenboden	Guánica	—	220	Beidellite
Alluvial	Aguirre	—	480	Beidellite
Do.	Coloso[1]	363, 278, 493	300	Kaolin
Do.	San Antón	1,572	380	Illite, kaolin, chlorite, beidellite
Do.	Toa	521, 547	420	Kaolin, beidellite
Do.	Viví	213, 158	240	Kaolin
Lithosols	Descalabrado	850	200	Illite
Do.	Múcara	125, 144, 2,961	360, 840	Beidellite
Do.	Pandura	—	220	Kaolin, illite
Mean		747	376	

[1] Soils wherein orthoclase feldspar was identified, together with plagioclase feldspars generally found in the other soils.

surface soils. No such correlation was found for the arid area. The range of values for the 117 soils analyzed is reported in table 2.

Capó (3) reported the contents of available potash, nitrogen, and phos-

phorus of 56 Puerto Rican soil samples as determined in pot tests using dwarf sorghum, hegari varitey, as a crop index. The available potash data

TABLE 5.—*Mean available potash extracted by sorghum and by 1-percent citric acid from some Puerto Rican soil groups and series from which feldspars were absent and in which clay minerals were identified*

Soil group	Soil series	K_2O per acre extracted by—		Clay mineral
		Sorghum	1-percent citric acid	
		Pounds	*Pounds*	
Red and Yellow Podzolic	Cabo Rojo	234	—	Beidellite, kaolin, montmorillonite
Do	Lares	408	400	Kaolin
Do	Los Guineos	570	220	Do.
Do	Moca	329	480	Kaolin, montmorillonite, illite
Reddish Brown Lateritic	Bayamón	884	120, 300	Kaolin
Do	Catalina	353, 400	300	Do.
Do	Cialitos	276	240	Kaolin, traces of illite
Do	Islote	—	520	Kaolin, illite
Do	Maleza	—	220	Kaolin
Do	Matanzas	—	300	Do.
Do	Río Piedras	296	300	Do.
Yellowish Brown Lateritic	Coto	421	420	Do.
Laterite	Nipe	—	720	Do.
Rendzina	Aguilita	903	380	Beidellite
Do	Soller	—	600	Kaolin
Planosol	Guayabo	—	280	
Do	Sabana Seca	204	220	Do.
Ground Water Podzol	Corozo	—	200	Do.
Lithosol	Tanamá	—	720	Kaolin
Mean		440	365	

or b values are reported in table 3 as calculated by the Mitscherlich's equation:

$$Y = A\ (1 - R^{x+b})$$

The mean R value[5] calculated for K_2O was 0.036 ± 0.008 with the nutrient concentration expressed in terms of grams per pot.

[5] The mean R values calculated for NH_3 and P_2O_5 were 0.095 ± 0.015, and 0.097 ± 0.021, respectively.

The mean available potash in pounds per acre extracted by the sorghum and by 1-percent citric acid from some Puerto Rico soils in which feldspars were present or absent, is reported in tables 4 and 5, respectively. The clay minerals identified in those soils are also reported.

In soils in which feldspars were present, the mean available potash extracted by the sorghum and by 1-percent citric acid was equivalent to 747 and 376 pounds of K_2O per acre, respectively. The sorghum extracted about twice as much potash. In soils from which feldspars were absent, the mean available potash extracted by the sorghum and by 1-percent citric acid was equivalent to 440 and 365 pounds of K_2O per acre, respectively. The presence or absence of feldspars did not affect the mean potash extracted from the soils by 1-percent citric acid. The potash extracted by the acid was exchangeable potash. The potash extracted generally from the soil by the sorghum, when feldspars were absent, was also exchangeable potash; but when feldspars were present, it was exchangeable potash plus available potash from other sources such as feldspars and micas.

The feldspars identified in those soils were generally of the plagioclase series, except for traces of orthoclase identified in the Coloso, Juncos, and Las Piedras, series (table 4). Since plagioclase feldspars should contain no potassium and since muscovite, another common potash mineral, was generally absent, except in Catalina clay (1) ,the source of the available potash extracted by the sorghum plant is of interest. The plagioclase feldspar minerals might constitute a source of potash since, according to Winchell (10), the albite molecule forms three crystal phases with sanidine, adularia, and microcline, all of which are potash feldspars of the general formula, $K_2O \cdot Al_2O_3 \cdot 6SiO_2$.

Response of Sugarcane in Puerto Rico to Potash Fertilizers and Foliar Analysis

Tests of the response of sugarcane in Puerto Rico to the application of potash fertilizers generally have been limited to a few soils.

Sugarcane varieties B.H. 10 (12), P.O.J. 2878 and M. 275 responded significantly (3) in the field to an application of 400 pounds K_2O per acre. The increase in yields for those varieties were 13, 20, and 19 percent, respectively. No significant yield response was obtained with the M. 28 variety. The amount of potash extracted by the sorghum from the soil sample of Coloso loam taken from that field was equivalent to 364 pounds of K_2O per acre.

The weighted mean reduction in yield from the omission of potassium from the fertilizer in a group of soils in Puerto Rico was reported elsewhere to be 7 percent (6); of which 11 percent was the figure for the humid area. Soils which responded to potash fertilizers, i.e., Coloso silty clay, Vega Alta

clay loam, and Mabí clay, all gave optimum yields when supplied with 150 pounds of K_2O per acre. In the irrigated areas in the southern part of the Island there was actually a 3-percent increase in yield when potassium was

TABLE 6.—*Mean yields of cane per acre for 9 consecutive crops[1] of P.O.J. 2878 with different potash levels added to acid Vega Alta clay loam*

Crop No.	Crop class	Yield of cane when indicated quantity of K_2O was used per acre per crop		
		90 pounds	180 pounds	270 pounds
		Tons	*Tons*	*Tons*
1	First ratoon	37.7[2]	38.5	38.3
2	Second ratoon	42.3	45.3	45.1
3	Third ratoon	36.1	39.1	37.6
4	Spring cane	49.8	51.2	51.8
5	First ratoon	47.9	50.8	50.0
6[3]	Second ratoon	57.1	61.4	60.9
7[3]	Third ratoon	45.7	50.4	48.9
8[4]	Fourth ratoon	43.2	46.2	45.7
9[4]	Fifth ratoon	40.5	44.8	42.5
Mean for 9 crops[5]		43.2	46.2	45.7

[1] Years 1943–52; a long-time experiment under the Soils Department, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R.

[2] Each value is the mean of 64 plots including 4 nitrogen levels: 103, 164, 225, 286 lbs. N per acre, and 2 phosphorus levels: 20 and 80 lbs. P_2O_5 per acre; and 8 replications.

[3] Responded to applications of potash in excess of 90 lbs. K_2O per acre. Optimum fertilizer level was 103 lbs. N, 20 lbs. P_2O_5 and between 90 and 180 lbs K_2O per acre, respecively.

[4] Responded to applications of potash and nitrogen in excess of 90 lbs. K_2O and 103 lbs. N per acre, respectively. Optimum fertilizer level was between 103 and 164 lbs. N, 20 lbs. P_2O_5, and between 90 and 180 lbs. K_2O per acre, respectively.

[5] Significant response to potash for the mean of the 9 crops. Least significant difference between means was 1.25 and 1.31 at 1- and 5-percent points, respectively. No response to nitrogen and phosphorus. Optimum fertilizer level for the mean of the 9 crops was 103 lbs. N, 20 labs. P_2O_5, and between 90 and 180 lbs. K_2O per acre, respectively.

omitted. The weighted mean reduction in yields from omission of nitrogen and phosphorus in that group of soils were 30 and 4 percent, respectively.

In a long-time field experiment what were essentially optimum sugarcane yields of P.O.J. 2878 were obtained in the first five consecutive crops, planted in acid Vega Alta clay loam of the humid area of Puerto Rico, with a minimum application of 90 pounds of K_2O per acre per crop per year,

as reported in table 6. The sixth and other consecutive sugarcane crops up to the ninth inclusive, and the 9-crop mean yield, responded significantly to the application of potash in excess of 90 pounds K_2O per acre.

No significant response to potash applications in excess of 90 pounds of K_2O per acre was obtained in each of 10 consecutive crops of sugarcane planted under irrigation in Vayas clay, in the arid area of Puerto Rico. The first four crops were of B.H. 10 (2) and the others of P.O.J. 2878.

No significant yield response of M. 336 sugarcane was obtained with applications of 19, 97, 175, and 253, pounds of K_2O per acre, respectively, in sand-lysimeter studies, as reported in table 7. No significant correlation

TABLE 7.—*Mean yields*[1] *of sugarcane and percentage of K in the leaves at various stages of growth when different levels of potash were applied*

Treatment in pounds per acre			Yield of cane per acre[2]	Potassium in leaves when sampled at—			
N	P_2O_5	K_2O		93 days	122 days	152 days	182 days
			Tons	*Percent*	*Percent*	*Percent*	*Percent*
240	175	19	13.32[3]	1.59[3]	1.22	2.69	1.13
240	175	97	18.26	2.37	2.37	2.56	1.78
240	175	175	18.19	2.78	1.98	2.21	1.12
240	175	253	18.51	2.94	2.04	2.34	1.00

[1] M.336 variety harvested at 9.5 months of age in irrigated sand lysimeters; minor elements were added. Unpublished data from experiment under Soils Department, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[2] Least significant differences are 5.56 and 7.70 tons cane per acre at 5- and 1-percent points, respectively.

[3] Each value represents the mean of 4 replications.

was obtained either between the K content of the cane leaves at about 3, 4, 5, and 6 months of age, respectively, and the yields of tons cane per acre or tons sugar per acre obtained with the four different levels of potash applied.

The range of K contents in the sugarcane leaves at a 3-month age varied from 1.59 to 2.94 percent, with the minimum and maximum applications of potash, respectively. Values below 1.80 percent K in 3-month leaf samples of sugarcane tend to indicate deficiency of this element for optimum yields (6) in Puerto Rico.

DISCUSSION

Orthoclase and muscovite, both primary minerals of the feldspar and mica group, respectively, were not generally found in the soils of Puerto Rico studied. The active tropical weathering process has transformed these potash minerals into other combinations difficult to identify. It is thought

that the potassium may be attached to the orthoclase feldspars, a group of sodium- and calcium-bearing minerals generally found in these soils.

The soils of Puerto Rico contain total potash in amounts varying from 200 to 18,200 pounds of K_2O per acre, as reported in this paper. The available potash content extracted with 1-percent citric acid varied from 60 to 1,920 pounds of K_2O per acre. The available potash content extracted in pot tests by dwarf sorghum, hegari variety, varied from 122 to 2,961 pounds of K_2O per acre. In soils in which feldspars were present, the mean available potash extracted by the sorghum was about twice that extracted by the 1-percent citric acid and the values were close together in soils from which feldspars were absent.

Chemical methods are therefore not always reliable to determine the potash that plants absorb from the soil

SUMMARY

The potash-bearing minerals, the total potash content in some profiles, the available potash range, and the mean available potash extracted by 1-percent ctiric acid and by dwarf sorghum (hegari) in pot tests, are reported here for Puerto Rican soil groups.

In soils in which feldspars were present, the mean available potash extracted by the sorghum and by citric acid was equivalent to 747 and 376 pounds of K_2O per acre, respectively. The sorghum extracted about twice as much potash.

In soils from which feldspars were absent, the mean available potash extracted by the sorghum and by citric acid was equivalent to 440 and 365 pounds of K_2O per acre, respectively.

Chemical methods are therefore not always reliable to determine the potash that plants absorb from the soil.

Tests of the response of sugarcane in Puerto Rico to the application of potash fertilizers generally have been limited to a few soils.

Optimum sugarcane yields of P.O.J. 2878 were obtained in the first five consecutive crops, in an acid soil of Puerto Rico, with a minimum application of 90 pounds of K_2O per crop per year. The sixth and later sugarcane crops, and the 9-crop mean yield, responded significantly to the application of potash in excess of 90 pounds of K_2O per acre.

No significant yield response was obtained with M. 336 grown in sand lysimeters with four increment levels varying from 19 to 253 pounds of K_2O per acre, respectively. No significant correlation was obtained either between cane yields and the K contents of the cane leaves at different stages of growth.

The 3-month cane leaves varied from 1.54 to 2.94 percent of K, with the minimum and maximum applications of potash, respectively.

RESUMEN

Se informan en este trabajo distintos aspectos sobre: los minerales potásicos, el contenido total de potasa de algunos perfiles, los valores mínimos y máximos de la potasa asimilable, el promedio de potasa asimilable extraído por un por ciento de ácido cítrico y por el sorgo enano, en pruebas con tiestos, todo en relación con algunos grupos de suelos de Puerto Rico.

En aquellos suelos en que se encuentran los feldespatos, el promedio de potasa asimilable, extraído por el sorgo y el ácido cítrico, fué 747 y 376 libras de K_2O por acre, respectivamente. El sorgo extrajo el doble de potasa.

En los suelos sin feldespatos, el promedio de potasa asimilable extraído por el sorgo y por el ácido cítrico, fué 440 y 365 libras de K_2O por acre, respectivamente.

Se concluye, que los métodos químicos no siempre resultan confiables para determinar con exactitud la cantidad de potasa que las plantas absorben del suelo.

La caña de azúcar generalmente ha respondido poco a las aplicaciones de los abonos potásicos en Puerto Rico.

Los mayores rendimientos de la variedad P.O.J. 2878 se obtuvieron en las primeras cinco cosechas consecutivas en un suelo ácido de Puerto Rico, con una aplicación mínima de 90 libras de K_2O por cosecha, por año. La sexta cosecha al igual que las otras tres seguidas, como también el promedio de las nueve cosechas, respondieron significativamente a la aplicación de potasa en exceso a 90 libras de K_2O por acre.

No hubo resultados significativos en los lisímetros de arena con cuatro niveles de aumento, los cuales variaron desde 19 hasta 253 libras de K_2O por acre, respectivamente. Tampoco, hubo correlación significativa entre los rendimientos de la caña y el contenido de potasa de sus hojas, en las cuatro épocas distintas en las cuales se hicieron las observaciones.

A los 3 meses el contenido de potasa en las plantas de caña varió entre 1.54 y 2.94 por ciento de K, respectivamente, en las aplicaciones mínimas y máximas de potasa.

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IDENTIFICATION AND DETERMINATION OF POLYBASIC ORGANIC ACIDS PRESENT IN WEST INDIAN CHERRIES (*Malpighia Punicifolia* L.) AND IN THREE VARIETIES OF GUAVA (*Psidium Guajava*)

Rafael Santini, Jr.[1]

INTRODUCTION

C. C. Gumarals and María de Abreu (1)[2], working with guavas and guava products reported that the two polybasic organic acids present in the fruit were levo-malic acid, which was said to be present in large quantities, and tartaric acid.

They said that citric acid is not present in the fruit and suggested that this lack could be used as a test for adulteration of jellies. Thus, if citric acid is present in the jelly, it could be regarded as adulterated.

Since there is no reference in their paper to the analytical method employed or to the varieties of guavas used, we decided to repeat this work quantitatively using different varieties of guavas. The same work was done with the West Indian cherry, a small fruit which has been described recently by C. F. Asenjo and C. G. Moscoso (2). There is nothing in the literature regarding the polybasic organic acids present in West Indian cherries. The only acid which has been identified and isolated in this fruit is the monobasic acid, ascorbic acid (3).

EXPERIMENTAL PROCEDURE

Three different varieties of guavas were employed in the work: Dominica Roja Agria, Dominica Blanca Agria, and Puerto Rico Rosada Agria. A complete quantitative determination of all acids present was made in the Dominica Roja Agria. The samples for analysis were prepared the same way for West Indian cherries as for guavas. The method for preparing the samples was as follows:

About 5 pounds of the fruit were cut in small pieces and then triturated in the Warring Blendor for 5 minutes. They were then passed through a china cap strainer with $\frac{1}{16}$-inch-diameter perforations. For the determination representative samples of 50 gm. were weighed in small containers and stored in the freezer. The method employed for the identification and determination was the Hartman Scheme for Polybasic Organic Acids (4).

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[2] Numbers in parentheses refer to Literature Cited, p. 198.

RESULTS

The results obtained with the West Indian cherries are tabulated in table 1. Each analysis was performed in duplicate.

TABLE 1.—*Results of the determination of all acids in West Indian cherries*

Acids	Aliquot 1	Aliquot 2	Average
	Meq./50 gm.	*Meq./50 gm.*	*Meq./50 gm.*
Total acidity	9.26	9.25	9.26
Ascorbic acid	2.35	2.40	2.38
Levo-malic acid	4.72	4.58	4.65
Dehydroascorbic acid	1.20	1.25	1.23
Nonidentified acids[1]	—	—	1.00

[1] Difference between the average of total acidity and the total of all acids identified.

TABLE 2.—*Results of the determination of levo-malic acid in 2 samples of West Indian cherries*

Sample No.	Aliquot 1	Aliquot 2	Average
	Meq./50 gm.	*Meq./50 gm.*	*Meq./50 gm.*
1	2.40	2.40	2.40
11	4.19	4.21	4.20

TABLE 3.—*Results of the determination of all acids in the Dominica Roja Agria variety of guava*

Acids	Aliquot 1		Aliquot 2		Aliquot 3		Average
	Meq./50 gm.	*Per cent*	*Meq./50 gm.*	*Percent*	*Meq./50 gm.*	*Percent*	*Meq./50 gm.*
Total acidity	14.13		14.10		—		14.12
Total ascorbic acid (includes dehydroascorbic acid)	.17		.18		.19		.18
Citric acid	12.40	(1.59)	11.70	.1.505	12.11	(1.55)	12.07
Tartaric acid	1.11	(.33)	1.09	(.33)	1.29	(.39)	1.16
Levo-malic acid	.47	(.063)	.47	(.063)	.45	(.061)	.46
Nonidentified acids[1]	—		—		—		.25

[1] Difference between the average of total acidity and the total of all acids identified.

Table 1 shows that the only polybasic organic acid present in large amounts is levo-malic acid. This was checked by preparing two different samples and determining levo-malic acid present in each. The results are given in table 2.

Neither tartaric nor citric acid were found to be present in the West Indian cherry by the method employed.

Just to have an idea of the pectin content of the West Indian cherry, an analysis was run in duplicate, using the alcohol-precipitation method. The results obtained showed an average of 0.32 percent.

When the Dominica Roja Agria variety of guavas was employed for the identification and quantitative determination of polybasic organic acids present, the results shown in table 3 were obtained.

Since C. C. Gumarals and María de Abreu emphasized the fact that citric acid was not present in guavas, we checked our work with two other varieties, the Dominica Blanca Agria and the Puerto Rico Rosada Agria. In both cases, citric acid was found to be present in large amounts. Tartaric

TABLE 4.—*Results of the determination of total acidity and of citric acid in 2 varieties of guavas*

Determination	Aliquot 1		Aliquot 2		Aliquot 3		Average
Dominica Blanca Agria variety							
	Meq./50 gm.	*Percent*	*Meq./50 gm.*	*Percent*	*Meq./50 gm.*	*Percent*	*Meq./50 gm.*
Total acidity	10.68		10.59		—		10.64
Citric acid	5.79	(0.75)	5.73	(0.73)	5.78	(0.74)	5.77
Puerto Rico Rosada Agria variety							
Total acidity	12.58		12.60		12.67		12.62
Citric acid	10.55	(1.35)	10.50	(1.35)	10.86	(1.39)	10.64

and levo-malic acid were determined qualitatively and they were found to be present in both varieties. Table 4 shows the results obtained for citric acid.

SUMMARY

Citric acid was found to be the polybasic organic acid present in large amounts in guavas. Therefore its determination cannot be used as a test for adulteration of guava jelly. Tartaric acid, as well as levo-malic acid, was also present in small amounts in the three varieties of guavas analyzed.

The only polybasic organic acid found in the West Indian cherry was levo-malic acid. Monobasic acid, ascorbic acid, and dehydroascorbic acid (lactone form) were also present in considerable quantities.

RESUMEN

El acido cítrico es el ácido orgánico polibásico que se encuentra en grandes cantidades en la guayaba. Por lo tanto su determinación no se puede

usar como una prueba para la adulteración de las jaleas de guayaba. El acido tartárico y el levo-málico, también se encontraron presentes en pequeñas cantidades en las tres variedades de guayaba analizadas.

El único ácido orgánico polibásico que se encontró en la acerola fué el levo-málico. El ácido ascórbico, que es un ácido monobásico, y el ácido dehydroascórbico (en forma de lactona) se encuentran también presentes en cantidades considerables.

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DETERMINATION OF REDUCING AND TOTAL SUGARS IN WEST INDIAN CHERRY (*Malpighia Punicifolia*, L.) JUICE

Rafael Santini, Jr.[1]

INTRODUCTION

West Indian cherries are described by C. F. Asenjo and C. G. Moscoso (1)[2] as a small fruit which weighs about 4 gm. and its size varies from 0.5 to 1 inch in diameter. Its color ranges from light green, when immature, to deep bright red when ripe. There are three small seeds in each cherry, and about 80 percent of the weight of the fruit is edible. Asenjo and Freire de Guzmán (2) reported that West Indian cherries contained from 1 to 3 gm. of ascorbic acid per 100 gm. of edible matter, and that the green fruit contained more ascorbic acid than the ripe. Values as high as 4.676 gm. per 100 gm. of edible pulp of green fruit were reported by H. Mustard (3).

The reaction involved in the Lane-Eynon method (4) for determining reducing and total sugars is one of oxidation and reduction. When this method was used with 25 samples of West Indian cherry juice, it was found that reducing sugars were higher than total sugars. Therefore, the method had to be modified for this specific juice. Ascorbic acid, which is present in large amounts in West Indian cherry juice, is a reducing substance which reacts with the Soxhlet solution as well as the methylene blue used in the Lane-Eynon method. Some ascorbic acid is lost during the process of inversion and, therefore, its contribution when determining reducing sugars is higher than when determining total sugars, making the value for total sugars appear to be smaller than that for reducing sugars.

EXPERIMENTAL PROCEDURE

Several attempts were made to titrate the Soxhlet solution directly with pure ascorbic acid solution, but it was impossible to obtain end points which checked. However, when a pure solution of ascorbic acid and glucose was prepared the determination was possible. The results are given in table 1, which shows that ascorbic acid affects the determination of glucose, giving higher results than the true value. The factor (*F*), glucose corresponding to 1 mg. of ascorbic acid, was found to be 0.686 mg.

To check whether this factor (*F*), 0.686 mg., could be applied in work

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[2] Numbers in parentheses refer to Literature Cited, p. 205.

with solutions of invert sugars, the following experiment was conducted:

Five 100 ml. volumetric flasks containing the same quantity of sucrose and different quantities of ascorbic acid, and 0.50 ml. of HCl (specific gravity 1.19) were left at room temperature for 24 hours. Then they were diluted to volume. Immediately prior to the titration of the Soxhlet solu-

TABLE 1.—*Quantity of glucose corresponding to 1 mg. of ascorbic acid as determined on a solution of pure ascorbic acid and glucose*

Glucose actually present per 100 mls. (milligrams)	Ascorbic acid actually present per 100 mls.	Glucose found per 100 mls.	Glucose apparently present due to effect of ascorbic acid	*F* (glucose corresponding to 1 mg. ascorbic acid)
	Milligrams	*Milligrams*	*Milligrams*	*Milligrams*
252.8	0.0	252.8	0.0	—
252.8	93.0	316.0	63.2	0.680
252.8	143.6	351.8	99.0	.689
252.8	195.9	387.6	134.8	.688
252.8	291.6	453.5	200.7	.688
Average.....				.686

TABLE 2.—*Data from an experiment carried out to determine whether the same F factor, 0.686 mg., could be used for invert-sugar as for reducing-sugar solutions*

Invert sugar actually present per 100 mls. final dilution (milligrams)	Invert sugar per 100 mls. final dilution found by titration	Ascorbic acid added per 100 mls. final dilution	Ascorbic acid per 100 mls. final dilution found after inversion	Ascorbic acid lost in 100 mls. of original solution during inversion	Invert sugar apparently present due to effect of ascorbic acid	Invert sugar found per 100 mls. of final dilution when corrected for ascorbic acid
	Milligrams	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*
200	263.9	106.6	91.4	76.0	63.1	200.8
200	293.4	145.3	129.9	77.0	89.6	203.8
200	370.3	255.1	249.9	27.0	172.3	198.0
200	264.9	99.5	91.6	39.4	63.2	201.7
200	327.6	199.0	191.8	41.0	132.3	195.3
Average.....						199.9

tion, 50 ml. from each flask were pipetted into five volumetric flasks of 250 ml., neutralized with sodium hydroxide solution, and diluted to volume. These solutions were used to titrate the Soxhlet solution. Immediately after titrating, the ascorbic acid present in the solution was determined by the iodate method (5). The results are given in table 2 and show that, after correcting for the ascorbic acid present after inversion, the invert sugar found corresponded to the true amount present. This proves that the factor used for reducing-sugar solutions could be used for invert-sugar solutions.

In table 3 results are given of an analysis made for reducing sugars in solutions containing sucrose, glucose, and different quantities of ascorbic acid. After determining reducing sugars by the Lane-Eynon method and correcting for the ascorbic acid present, the reducing sugars found corresponded to the glucose known to be present.

The same procedure was followed with the West Indian cherry juice, that is, the ascorbic acid was determined both before and after inversion, and then the determination of sugars by the Lane-Eynon method was corrected accordingly.

Five different samples of juices were stored at room temperature and at 45°F. Determinations of ascorbic acid, reducing sugars, and total sugars were performed periodically. The results are shown in table 4.

TABLE 3.—*Data from an experiment carried out to determine reducing sugars in solutions containing known quantities of sucrose, glucose, and ascorbic acid*

Glucose added per 100 mls. (milligrams)	Sucrose added per 100 mls.	Reducing sugar per 100 mls. found by titration	Ascorbic acid added per 100 mls.	Reducing sugar apparently present due to effect of ascorbic acid	Reducing sugar corrected for ascorbic acid
	Milligrams	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*
290.3	199.5	374.0	128.4	88.6	285.4
290.3	199.5	461.0	256.8	177.2	283.8

DISCUSSION

The data in table 4 show that the only difference obtained by storing the juice at room temperature and at 45°F. was that the ascorbic acid is lost less readily at 45°F. than at room temperature.

Statistical analysis of the data obtained from the different juices showed that there was no significant difference between corrected reducing sugars and corrected total sugars. It also proved that the lengths of the storage periods were not significant, that is, the sugar content did not change after storing for 1 year. The statistical analysis revealed that, if sucrose is present in the juice, it must be in quantities so small that it cannot be determined by this method. The results had to be expressed to only one decimal place, since the standard error for the determination of sugar in this juice was ± 0.21 and the least significant difference at 5 percent was ± 0.42.

It can be concluded that, in the specific case of the West Indian cherry juice, when using the Lane-Eynon method and correcting for ascorbic acid, reducing sugars are equal to total sugars and that by determining the former, the sugar content of the juice is known. This eliminates the trouble of having to determine total sugars and ascorbic acid after inversion. However, in any other fruit juice which is rich in ascorbic acid and which con-

TABLE 4.—*Determination of sugars in samples of West Indian cherry juice held at room temperature and at 45°F.*

Age of juice (months)	Corrected reducing sugar	Corrected total sugars	Ascorbic acid per 100 ml. of juice before inversion	Ascorbic acid per 100 ml. of juice after inversion
	Sample 1, room temperature			
	Percent	*Percent*	*Milligrams*	*Milligrams*
0	3.6	3.7	1,120	934
1	3.6	3.6	1,060	855
2	3.6	3.7	1,060	734
3	3.7	3.6	975	802
6	3.7	3.7	744	651
12	3.7	3.6	524	464
	Sample 1, 45°F.			
0	3.6	3.7	1,120	934
1	3.5	3.6	1,120	995
2	3.6	3.6	1,180	974
3	3.6	3.5	1,120	1,010
6	3.7	3.8	1,020	883
12	3.5	3.4	1,010	859
	Sample 2, room temperature			
0	3.0	3.0	913	796
1	3.0	3.0	874	634
2	3.0	3.2	794	577
3	3.0	3.2	770	430
6	3.1	3.1	612	475
12	3.1	3.3	371	309
	Sample 2, 45°F.			
0	3.0	3.0	913	796
1	2.9	2.9	958	823
2	3.1	3.2	897	740
3	3.0	3.1	896	624
6	3.1	3.1	813	684
12	3.2	3.3	723	668
	Sample 3, room temperature			
0	3.4	3.6	1,030	788
1	3.4	3.5	970	748
2	3.4	3.4	868	691
3	3.5	3.6	854	562

TABLE 4.—*Continued*

Age of juice (months)	Corrected reducing sugar	Corrected total sugars	Ascorbic acid per 100 ml. of juice before inversion	Ascorbic acid per 100 ml. of juice after inversion
	Sample 3, room temperature—Continued			
	Percent	*Percent*	*Milligrams*	*Milligrams*
6	3.7	3.7	670	532
12	3.4	3.7	406	200
	Sample 3, 45°F.			
0	3.4	3.6	1,030	788
1	3.4	3.4	1,080	938
2	3.4	3.3	992	897
3	3.4	3.4	985	817
6	3.5	3.4	915	801
12	3.5	3.7	823	542
	Sample 4, room temperature			
0	3.5	3.5	1,140	897
1	3.5	3.4	1,030	968
2	3.5	3 6	933	780
3	3.4	3.5	907	707
6	3.6	3.7	859	662
12	3.5	3.5	449	365
	Sample 4, 45°F.			
0	3.5	3.5	1,140	897
1	3.4	3.5	1,150	951
2	3.4	3.4	1,060	938
3	3.5	3.5	1,060	912
6	3.7	3.7	1,020	872
12	3.6	3.7	901	785
	Sample 5, room temperature			
0	3.4	3.4	—	—
1	3.4	3.5	843	558
2	3.4	3.3	797	599
3	3.3	3.3	741	589
6	3.3	3.4	619	509
12	3.4	3.6	365	301

TABLE 4.—*Continued*

Age of juice (months)	Corrected reducing sugar	Corrected total sugars	Ascorbic acid per 100 ml. of juice before inversion	Ascorbic acid per 100 ml. of juice after inversion
	Sample 5, 45°F.			
	Percent	*Percent*	*Milligrams*	*Milligrams*
0	3.4	3.4		
1	3.3	3.4	946	850
2	3.3	3.2	901	797
3	3.3	3.2	869	788
6	3.4	3.3	823	744
12	3.5	3.5	759	650

tains a significant quantity of sucrose, the corrected total sugars as well as the corrected reducing sugars must be determined.

SUMMARY

(1) Ascorbic acid is the substance responsible for the discrepancies found in the determination of reducing sugars and total sugars by the Lane-Eynon method. By correcting for ascorbic acid using the factor (*F*) 0.686, the discrepancy is eliminated and the Lane-Eynon method can be used.

(2) To determine the total sugar content of West Indian cherry juice corrected reducing sugars only need be assayed, because it was proved experimentally and statistically that there is no significant difference between corrected reducing and corrected total sugars.

(3) The sugar content of West Indian cherry juices stored at room temperature and at 45°F. does not change appreciably after 1 year.

(4) At 45°F. ascorbic acid is lost less readily than at room temperature, but temperature produces no significant difference in the true sugar content of the juice.

RESUMEN

(1) La substancia responsable de las discrepancias encontradas en la determinación de azúcares reductoras y azúcares totales por el método de Lane-Eynon es el ácido ascórbico. Si se corrige para el ácido ascórbico, usando el factor 0.686, la discrepancia desaparece y el método de Lane-Eynon es aplicable.

(2) Para conseguir el contenido de azúcares en el jugo de acerola, lo único que hay que determinar son los azúcares reductores corregidos, ya que se ha probado experimental y estadísticamente que no hay ninguna diferencia significativa entre azúcares reductores corregidos y azúcares totales corregidos.

(3) El contenido de azúcares en el jugo de acerola almacenado a 45°F y a temperatura de salón no varía después de 1 año.

(4) Cuando el jugo de acerola se almacena a 45°F la cantidad del ácido ascórbico disminuye con menos prontitud que cuando se almacena a temperatura de salón. Sin embargo la temperatura no afecta significativamente el contenido de azúcares en el jugo.

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THE BENEFICIAL EFFECT OF FILTER-PRESS CAKE ON PINEAPPLE YIELDS UNDER FIELD CONDITIONS[1]

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INTRODUCTION

In previous papers (1, 2, 3)[3] the influence of filter-press cake upon pineapple growth, development, and production has been discussed. The results from pot experiments comprising a plant-crop and first-ratoon-crop cycle indicated that pineapple plants grown in soil with the top 6 inches of which filter-press cake had been mixed, developed more vigorously and were of a darker green color, their leaves were wider and their stem and flower stalks thicker than those of pineapple plants treated otherwise. Furthermore, they were the heaviest fruit yielders, and were superior in slip and sucker production.

These encouraging preliminary results from pot experiments at Río Piedras suggested the possibility of using filter-press cake as a soil amendment in pineapple fields, in conjunction with fertilizers, so as to increase yields of pineapple, low yields being a limiting factor to pineapple-growing in Puerto Rico. They further led to additional work to test the possibility of successfully reproducing under field conditions the results obtained in pots.

This paper reports the results obtained from two field experiments established in representative pineapple-growing areas of the Island. Different rates of filter-press cake were applied at both sites to determine the minimum application required for maximum crop yields at each site. Two levels of fertilizer were also tested at both locations in combination with various quantities of filter-press cake.

MATERIALS AND METHODS

Two fields were selected, one at Palo Blanco, Arecibo, in northern Puerto Rico, and one at the farm of the Corozal Agricultural Experiment Substation in the interior. At Arecibo the soil had been classified as Bayamón silty clay, an acid, deep, lateritic soil of the coastal plain derived from

[1] This paper constitutes the third in a series on the same general subject, the first and second of which will be found in the *Journal of Agriculture* **36** (3) 255–301 1952.

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[3] Numbers in parentheses refer to Literature Cited, p. 212.

limestone. At Corozal, the soil is a typical, nearly level, medium-friable Lares clay occurring in terrace formations and derived from material washed from the lower Tertiary clays and shales.

Plots of 20 x 8 feet, comprising an area of $\frac{1}{272}$ of an acre, were found to be most adequate for the field work. On each plot 3 rows of pineapples were planted, 15 plants to the row. At this rate a total of 12,240 plants would be required to plant an acre of pineapple. Slips of the Red Spanish variety, the commercial pineapple of the Island, were planted on September

TABLE 1.—*Soil treatments used for pineapple growing at the experimental fields in Arecibo and Corozal*

Treatment identification letter	Description of soil treatments[1]		
	Filter-press cake applied per A.	Fertilizer used	
		Amount and analyses	Application
	Tons		*Number*
A	8	1,500 lbs. of 12-6-10	3
B	16	1,500 lbs. of 12-6-10	3
C	24	1,500 lbs. of 12-6-10	3
D	32	1,500 lbs. of 12-6-10	3
E	32	1,500 lbs. of 12-6-10	1
F	32	3,000 lbs. of 12-6-10	4
G	32	3,000 lbs. of 12-6-10	4
H	32	0	—
I	32	360 lbs. NH_3 + 180 lbs. P_2O_5	4
J	32	180 lbs. P_2O_5 + 240 lbs. K_2O	4
K	32	360 lbs. NH_3 + 240 lbs. K_2O	4
L	0	3,000 lbs. of 12-6-10	4
M	0	3,000 lbs. of 12-6-10 + lime[2]	4

[1] In all treatments except in F and L, 2 iron sprays were used on the plants, as is customary in commercial pineapple cultivation.

[2] Soil limed with calcium carbonate to raise pH up to 6.5.

18 and 25, 1950, at Corozal and Arecibo, respectively. Fertilizer applications as shown in table 1, were made at both locations in October 1950, and during January and May of the following year. Iron sprays were used where required (table 1), towards the end of December 1950 and again in the following March.

Thirteen treatments were tested at both fields, each replicated eight times in an incomplete-block design. A detailed record of the treatments used can be found in table 1. The filter-press cake was 3 months old at the time of application and contained about 70-percent moisture. It was worked into the top 4 to 6 inches of soil prior to planting the pineapple slips.

To induce flowering, the plants from both experiments were treated with

acetylene approximately 1 year after being planted. This consisted of spraying the crown of the plant with 25 or 30 ml. of a solution made by dispersing 2 ounces of calcium carbide in 5 gallons of water in a closed container.

In April 1952, when the plants were about 18 months old, the fruits were harvested as is usual in commercial pineapple fields. The criteria used in evaluating the effect of the treatments were the weight and amount of marketable fruits, the mean production per acre, and the slip production per plant. All data on weight of fruit, yield per acre, and slip production were statistically analyzed.

RESULTS AND DISCUSSION

Data on mean weight of fruit, mean yield per acre, and slip production per plant are given in table 2 for the Arecibo experiment. A study of the data reveals that larger fruits were obtained from plots receiving filter-press cake at the rate of 32 tons to the acre (treatment D) than from plots receiving lesser amounts, when the fertilizer application was at the rate of only 1,500 pounds to the acre (treatments A and B). Furthermore, significantly heavier yields were obtained from plots receiving filter-press cake at the rate of 32 tons to the acre than from those receiving it at rates of only 8 and 16 tons (treatments A and B). Complete omission of the fertilizer (treatment H) led to highly significant reductions in yield and weight of fruit, even when the same quantities of filter-press cake were used (treatments F and G). When nitrogen was omitted from the fertilizer (treatment J), both the mean weight of the fruit and the total production of fruit were markedly reduced. Omissions of either potash (treatment I) or phosphoric acid (treatment K) did not significantly reduce yields. The use of fertilizers at the rate of 3,000 pounds to the acre (treatment L) resulted in high yields even though no filter-press cake was applied. However, liming the soil to pH 6.5 (treatment M) affected the production of fruit adversely. At this location the use of 32 tons of filter-press cake per acre, in conjunction with 1,500 pounds of fertilizer proved sufficient for maximum yields. The use of 360 pounds of NH_3 in addition to 32 tons of filter-press cake per acre would perhaps also be sufficient.

Whether the fertilizer was applied all at once or split in three or four applications had no effect on the final yields and weights of fruits. Spraying with ferrous sulfate was not effective either.

Thus, it seems that, in this area, when at least 32 tons of filter-press cake are applied to the acre, there is no need to apply more than half the fertilizer that is usually used in pineapple fields. When only half of the fertilizer generally used was applied, the plants from the plots which received applications of filter-press cake at the rate of 32 tons (treatments D and E) to the acre produced more slips than those which received 8 tons (treatment A) of filter-press cake to the acre. Omissions of nitrogen (treatment

J) from the fertilizer or of filter-press cake (treatments L and M) resulted in a significant reduction of the slips produced per plant.

Table 3 shows the mean weight of fruits and mean yields of fruit to the acre for the Corozal experiment. The results from this experiment further confirm some of the conclusions obtained from the Arecibo experiment. There was, however, a marked response to potash, as well as to nitrogen,

TABLE 2.—*Mean fruit weight, pineapple yield per acre, and slip production per plant at the filter-press-cake experimental field, Palo Blanco, Arecibo*

Treatment identification letter	Mean weight of fruit	Mean yield of fruit per acre	Mean slips per plant
	Pounds	*Tons*	*Number*
A	2.92	17.87	3.3
B	3.00	18.36	3.7
C	3.22	19.71	3.8
D	3.38	20.69	4.2
E	3.24	19.83	4.6
F	3.51	21.48	5.1
G	3.47	21.14	4.7
H	2.82	17.26	3.8
I	3.40	20.81	4.6
J	3.06	18.73	3.9
K	3.41	20.87	5.0
L	3.32	20.32	3.9
M	2.99	18.30	3.4

L.S.D. between mean weight of fruit at the:	
5-percent level	0.32 pounds
1-percent level	.42 pounds
L.S.D. between mean yield of fruit per acre at the:	
5-percent level	1.96 tons
1-percent level	2.57 tons
L.S.D. between mean number of slips at the:	
5-percent level	0.9 slip
1-percent level	1.2 slip

in this experiment. The omission of either one of these elements resulted in a decrease of about 3 tons of pineapple to the acre (see table 3 and compare treatments I and J with F, G, and K) even at the highest level of filter-press cake.

The soils of the Lares series of Corozal are unable to supply enough available potash for a crop of pineapples. In the Bayamón soils of the Arecibo coastal plains the omission of potash was not detrimental to pineapple production when 32 tons of filter-press cake were applied in addition to inorganic nitrogen and phosphorus. The pineapples from plots not receiving filter-press cake, (treatments L and M) even though they received

a complete fertilizer application of 3,000 pounds on the acre basis, produced the smallest fruits and the lowest total yields to the acre. In the Corozal and other areas having similar soil conditions the necessity for making large applications of fertilizer, such as the 3,000 pounds to the acre of a 12–6–10 fertilizer used in these experiments, is rather marked, even when filter-press cake is used at a rate of 32 tons to the acre. (Compare treatments F and G with mean of treatments D and E). In other words,

TABLE 3.—*Mean fruit weight and yield per acre of pineapples grown at the filter-press cake experimental field, Corozal Substation Farm*

Treatment identification letter	Mean weight of fruit	Mean yield of fruit per acre
	Pounds	*Tons*
A	2.64	16.16
B	2.78	16.98
C	2.89	17.71
D	2.96	18.08
E	2.79	17.07
F	3.23	19.76
G	3.44	21.03
H	2.64	16.17
I	2.76	16.90
J	2.71	16.61
K	3.25	19.86
L	2.36	14.42
M	2.56	15.66

L.S.D. between mean weight of fruit at the:
5-percent level ..... 0.31 pounds
1-percent level ..... .42 pounds
L.S.D. between mean yield of fruit per acre at the:
5-percent level ..... 1.92 tons
1-percent level ..... 2.54 tons

both heavy fertilization and heavy applications of filter-press cake are required for maximum yields. However, applications of 32 tons of filter-press cake with only 1,500 pounds of fertilizer will produce significantly higher yields and heavier fruits than applications of twice as much fertilizer if filter-press cake is omitted. (Compare treatment D with treatments L and M).

In Arecibo and related areas considerable savings can be made by the farmers without decreasing yields, because filter-press cake can be obtained free from most sugar mills and hauled to the farm at a relatively low cost. Furthermore, the Production and Marketing Administration makes benefit payments to farmers of $1[4] per ton of filter-press cake applied. These pay-

[4] Only 50 cents for sugarcane farmers, but $1 for all others.

ments, in addition to increasing the farmers' gross income, are a rather strong incentive to continuous and more widespread use of filter-press cake and, consequently, will help to restore and maintain an adequate level of organic matter in the soil. Details on the possible effects of the filter-press cake upon soil conditions are presented in a second article in this issue of the *Journal of Agriculture*.

DISCUSSION

It is of interest to point out that, throughout their growth period, the pineapple plants which developed in soil previously treated with filter-press cake at both locations were always superior in vigor, the leaves were greener in color, they were taller, and their stems and flower stalks were thicker than those of pineapple plants given other treatments.

Field work with filter-press cake will necessarily be expanded. The two field experiments at Arecibo and Corozal will be continued to complete the crop cycle. Meanwhile, the results herein reported for the plant crop provide rather important reference points as to what may be expected from filter-press cake applications to pineapple fields.

The economic implications of applying only half of the fertilizer generally used, when filter-press cake is available, can be far reaching in areas where conditions similar to those around Arecibo prevail. About the same bulk of pineapple can be produced much cheaper by using 1,500 pounds of fertilizer and filter-press cake than when 3,000 pounds to the acre of fertilizer are used. In other places, such as the Corozal region, high levels of both filter-press cake (32 tons to the acre) and fertilizer (3,000 pounds to the acre) are necessary for maximum yields. Nitrogen is a limiting factor for pineapple production in Arecibo while both nitrogen and potash are limiting factors at Corozal.

SUMMARY

Data from two field experiments located in typical pineapple growing areas in the northern and interior regions of Puerto Rico are reported here. Pineapple plants grown in soil to which filter-press cake was applied previous to planting developed vigorously and were of a dark-green color. Their leaves were wider and their stems and flower stalks thicker than those of pineapple plants given other treatments.

At one location, Arecibo, pineapple plants grown in soil receiving at least 32 tons of filter-press cake to the acre, in addition to 1,500 pounds of a 12–6–10 fertilizer, produced yields as high and fruits as large as plants grown in soil receiving twice as much fertilizer but no filter-press cake. Omissions of nitrogen or filter-press cake resulted in reduced yields.

The possibility of using filter-press cake more extensively in pineapple fields in the Arecibo and related areas, in conjunction with smaller doses

of fertilizers than are generally used, deserve careful consideration from the growers.

At the second location, Corozal, 3,000 pounds of fertilizer in addition to 32 tons of filter-press cake to the acre proved to be necessary for maximum yields. Omissions of both potash and nitrogen are detrimental to pineapple production.

RESUMEN

Se presentan aquí datos de dos experimentos sobre abonamiento de la piña llevados a cabo en áreas representativas en el Norte y en el Interior de la Isla. Cuando se trató el suelo con cachaza, las plantas de piña se desarrollaron vigorosamente y tuvieron un color verde oscuro. Las hojas fueron más anchas y los tallos y pedúnculos florales más gruesos que los de las plantas que se desarrollaron en las parcelas sometidas a otros tratamientos.

En la zona de Arecibo, en el suelo que recibió no menos de 32 toneladas de cachaza por acre, además de 1,500 libras de un abono 12–6–10, las plantas de piña produjeron rendimientos tan altos y frutas del mismo tamaño que aquellas que se desarrollaron en el suelo, al cual se le había aplicado el doble de la cantidad de abono antes mencionada, pero donde se había omitido la cachaza. Cuando se omitió el nitrógeno del abono, o no se aplicó la cachaza, se redujeron los rendimientos.

Los resultados de estos experimentos señalan la posibilidad de usar más ventajosa y extensivamente la cachaza, conjuntamente con menores cantidades de abono que las que se usan ahora en los plantíos de piña de la zona de Arecibo. En la zona de Corozal se necesitan 3,000 libras de abono, además de 32 toneladas de cachaza por acre de piña para poder obtener los rendimientos máximos de esta cosecha. La omisión de la potasa y la del nitrógeno en los abonos para piña perjudica los rendimientos.

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THE EFFECT OF FILTER-PRESS CAKE ON THE PHYSICAL AND CHEMICAL PROPERTIES OF SOILS[1]

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INTRODUCTION

The growing appreciation of the beneficial effects of filter-press cake upon crop yields has led to a number of theories concerning the mechanisms involved. Some are of the opinion that filter-press cake promotes better plant growth and production through the release to plants of some unidentified organic growth regulator. Others believe that it raises and balances the fertility level of the soil through the release of nitrogen, potash, and other plant nutrients. Still others feel that it is through their effect on the physical properties of soils as a medium for plant growth that filter-press-cake applications result in heavier crop yields. In all probability increased crop yields are the resultant of all three mechanisms or at least of the last two: Beneficial effect on the fertility level and on the physical properties of soils.

The literature concerning the use of filter-press cake in agriculture is very limited. Although a number of reports have appeared sporadically during the past decade, most of them have been merely the results of random observations unfortified by experimental evidence.

Early experimental work at Río Piedras indicated that an application of 20 tons to the acre of filter-press cake increased yields of cucumbers (1)[3], Hernández-Medina (4, 5, 6) reported that pineapple plants grown in pots filled with soil the top 4 or 6 inches of which had been mixed with filter-press cake, developed vigorously and were of a dark-green color. Their leaves were wider and their steams and flowers stalks thicker than those given other treatments. Furthermore, they were the heaviest yielders of fruit and produced the largest number of slips and suckers per plant.

Work under field conditions in the Arecibo coastal area has shown that,

[1] This paper constitutes the fourth in a series on the same general subject, the first and second of which will be found in the *Journal of Agriculture* **36** (3) 255–301 1952, and the third in this issue of the *Journal*, pp. 206–12.

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[3] Numbers in parentheses refer to Literature Cited, pp. 222–3.

when filter-press cake is applied to the soil at the rate of 32 tons to the acre, maximum yields of pineapple can be obtained with applications of a 12–6–10 fertilizer at the rate of only 1,500 pounds to the acre. At Corozal, however, both heavy applications of filter-press cake (32 tons) and of fertilizer (3,000 pounds) were necessary for obtaining maximum yields (7).

This paper reports on the soil conditions at the two sites where the latest field experiments were conducted by Hernández-Medina, et al. (7). It presents data on the physical and chemical properties of soils which received different quantities of filter-press cake, about 18 months after establishing the treatment differentials.

NATURE AND PROPERTIES OF FILTER-PRESS CAKE

Filter-press cake or filter-press mud is a byproduct from the sugar mills. It is generally obtained in Puerto Rican mills from Oliver and press filters.

TABLE 1.—*Production of filter-press cake per ton of cane and polarization values obtained from 4 sugar mills in east-central Puerto Rico, 1952*[1]

Mill	Filter-press cake per ton of cane	Polarization
	Percent	*Degrees*
Juncos	2.91	3.681
Pasto Viejo	2.36	4.194
Santa Juana	3.57	2.380
Cayey	2.84	5.567

[1] Personal communication from Mr. M. A. del Valle, President and General Manager of the Eastern Sugar Associates, to Dr. J. A. Bonnet, Head, Soils Department, Agricultural Experimental Station, University of Puerto Rico, Sept. 5, 1952.

It is a soft, spongy, lightweight, amorphous material that can absorb rather large quantities of water when dry. As obtained from the mills it generally contains between 60 to 80 percent of moisture and 2 to 4 percent of sucrose. The mean production of filter-press cake is estimated to range from 1.25 percent to over 3.00 percent of the weight of the cane. On the basis of 12,000,000 tons of millable cane per year, the annual production of filter-press cake should range from 150,000 to 360,000 tons. Table 1 gives data on the production of filter-press cake per ton of cane for four sugar mills in east-central Puerto Rico.

Table 2 gives the range of values for the chemical composition of various samples of filter-press cake taken from a number of sources. Some of the samples were obtained from the South Puerto Rican Sugar Co. in southern Puerto Rico, others from mills in the east-central region, and others from the northern region. Compared to a commercial fertilizer, filter-press cake is low in nutrient content. However, as compared with a soil, it is rather

high in organic matter and nutrients. It contains somewhat less moisture than fresh animal manures, but is much higher in nitrogen and phosphoric acid. It can probably supply about the same potash as horse and cow manures (9).

As a fertilizer filter-press cake must be rated as rather low in nutrients and somewhat unbalanced. Consideration must also be given to the decomposition processes that follow its application to the soil. In usual farm practice, because of the large quantities of filter-press cake applied per unit area (anywhere from 15 to 100 tons to the acre), relatively large quantities of total nutrients are actually added to the soil.

Moreover, large quantities of rather stable organic matter are actually added to the soil when incorporating filter-press cake. The unquestionable benefits of organic matter, not merely from the standpoint of soil fertility, but as a soil conditioner as well, have often been observed. Field observa-

TABLE 2.—*Range in chemical composition of filter-press cake from various sources*

Constituent	Range of values	Constituent	Range of values
	Percent		*Percent*
Moisture	60–80	K_2O	0.46–0.89
Organic matter	20–30	CaO	3.11–4.13
Sucrose	2–4	MgO	2.38
Nitrogen	0.94–1.31	Fe_2O_3 and Al_2O_3	1.70
P_2O_5	1.66–2.74		

tions indicate that, when applied in large quantities to heavy soils, structural conditions are improved; water retention at low tensions is generally increased in light-texture soils with low organic-matter contents.

MATERIALS AND METHODS

Two fields were selected, one at Palo Blanco, Arecibo, in northern Puerto Rico, and one at the farm of the Corozal Agricultural Substation, in the interior. At Arecibo, the soil has been classified as Bayamón silty clay, an acid, deep, lateritic soil of the coastal plains derived from limestone. At Corozal, the soil is a typical, nearly level Lares clay, a medium-friable soil occurring in terrace formations and derived from material washed from the lower Tertiary clays and shales.

A detailed account of all the field operations concerning the soil- and crop-management techniques employed during the course of the experiment has been reported elsewhere (7). For the objectives of the investigation herein reported soil samples were taken some 18 months after establishing the treatment differentials. Samples were taken only from the plots treated

as follows:[4]

Treatment B: 16 tons of filter-press cake and 1,500 pounds of a 12-6-10 fertilizer to the acre.

Treatment D: 32 tons of filter-press cake and 1,500 pounds of a 12-6-10 fertilizer to the acre.

Treatment L: No filter-press cake, 3,000 pounds of a 12-6-10 fertilizer to the acre.

Bulk soil samples to a depth of 6 inches were taken both at the Arecibo and Corozal experimental fields. At the latter location, undisturbed soil cores were also taken from the 1- to 4-inch layer of soil by using a special sampler of the Bradfield type, 3 inches in diameter by 3 inches in length.

Permeability measurements were made in undisturbed soil cores by recording the rate at which water moved through a column of saturated soil at a known head. Quick drainage was determined by placing the soil core in a Büchner funnel, setting a 60-cm. tension, and measuring the water drained out at the end of 15 minutes. The water retained at pF 1.78 was measured by bringing the soil core to equilibrium with a 60-cm. tension and determining the variation in weight of the core. Water remaining at pF's 2.7 and 4.2 was determined by submitting saturated soil samples to pressures of 0.5 and 15 atmospheres, respectively, in special pressure plates. The maximum saturation was calculated from the above data. The available water was considered to be in the range between pF 1.78 and pF 4.2.

The soil core was finally dried in the oven at 110°C. As the samples used had a definite known volume, the bulk density of the soil was calculated by dividing the net dry weight of soil by its original volume. The pore space was then calculated by assuming a specific gravity value of 2.65. The air porosity was considered to be the difference between total porosity and water porosity (water retained at pF 1.78).

The pH was determined electrometrically by means of a Macbeth pH-meter. Total nitrogen was determined by the standard Kjeldahl method and the organic matter by the chromic acid titration method. The carbon-nitrogen ratio was subsequently calculated from the above data. The exchange capacity was determined by the ammonium acetate method. Exchangeable calcium, magnesium, and manganese were determined by methods developed by Peech (11). Available phosphorus and iron in the soil were extracted with Morgan universal solution as described by Bonnet and Riera (2). Phosphorus was then determined colorimetrically by the procedure developed by Wolfe (12), and iron by the method of Saywell and Cunningham, as described by Parks, et. al. (10).

[4] For a detailed description of each treatment see Hernández-Medina, E., et al. The beneficial effect of filter-press cake on pineapple yields under field conditions, *J. Agr. Univ. of P. R.* **37** (3) 206–12 1953.

RESULTS AND DISCUSSION

The results of the chemical analyses of the soils taken from the Arecibo and Corozal filter-press cake experimental fields are shown in tables 3 and 4. At Arecibo the range of pH values for all plots was from 4.1 to 5.6 with a mean of pH 4.6 for soils under all treatments combined. There were no significant differences between the means of the treatments. At Corozal there was a narrower range of variation considering all plots, but the pH

TABLE 3.—*Mean pH, nitrogen, organic matter, and C/N ratio of soils from the filter-press cake experimental fields at Arecibo and Corozal*

Treatment identification letter	Description of soil treatments		pH	Nitrogen	Organic matter	C/N ratio
	Filter-press cake	Fertilizer 12-6-10				
	Results at Arecibo[1]					
	Tons/acre	*Pounds/acre*		*Percent*	*Percent*	
B	16	1,500	4.5	0.144	2.41	9.6
L	32	1,500	4.7	.146	2.42	9.7
D	0	3,000	4.6	.138	2.34	9.9
	Results at Corozal[2]					
B	16	1,500	4.4	0.156	2.73	10.6
L	32	1,500	4.4	.175	2.81	9.4
D	0	3,000	4.2	.155	2.26	8.8
[1] L.S.D. at the 5-percent level			0.37	0.014	0.37	1.03
L.S.D. at the 1-percent level			.51	.019	.51	1.40
[2] L.S.D. at the 5-percent level			0.12	0.027	0.55	3.17
L.S.D. at the 1-percent level			.17	.037	.75	4.32

of the plots receiving either 16 or 32 tons of filter-press cake to the acre was significantly higher than that of the control plots. The mean nitrogen content of soils under all combined treatments was 0.142 for Arecibo and 0.162 for Corozal. There were no significant differences between the mean nitrogen content of soils of the plots to which filter-press cake was added and those which did not receive additional organic matter. The differential application of fertilizer to these plots may account for the apparent uniformity in spite of the organic material added to some of them.

Although no significant differences could be measured statistically in the organic-matter content of the plots receiving 0, 16, and 32 tons of filter-press cake to the acre, organic-matter levels were consistently lower on all

plots to which no filter-press cake was added than on those which received either 16 or 32 tons of the filter-press cake. The differences are particularly noticeable at Corozal. Data in table 2 indicate that filter-press cake has a rather wide C/N ratio of about 50:1. By the time it becomes an integral part of the soil, this ratio must be narrowed down to 10:1.

Assuming a moisture content of 70 percent, 16 tons of filter-press cake can become 0.96 ton of organic matter with a C/N ratio of 10:1, which is

TABLE 4.—*Total exchange capacity; exchangeable calcium, magnesium, and manganese; and available phosphorus and iron for soils from the filter-press cake experimental fields at Arecibo and Corozal*

Treatment identification letter	Description of soil treatments		Total exchange capacity	Exchangeable cations[1]			Available phosphorus	Available iron
	Filter-press cake	Fertilizer 12-6-10		Calcium	Magnesium	Manganese		
	Results at Arecibo							
	Tons/acre	*Pounds/acre*	*M.e.*	*M.e.*	*M.e.*	*M.e.*	*Percent*	*Percent*
B	16	1,500	8.1[2]	1.75	0.01	0.30	0.0005	0.0004
D	32	1,500	8.3[2]	1.15	.03	.24	.0005	.0004
L	0	3,000	8.2[2]	1.68	.02	.33	.0005	.0005
	Results at Corozal							
B	16	1,500	12.6[3]	2.54	0.33	0.18	0.0006	0.0016
D	32	1,500	12.1[3]	2.12	.14	.31	.0005	.0012
L	0	3,000	12.8[3]	1.08	.02	.47	.0005	.0012

[1] Expressed as m.e. per 100 gm. of dry soil
[2] L. S. D. at the 5-percent level 1.16
L. S. D. at the 1-percent level 1.58
[3] L. S. D. at the 5-percent level 0.67
L. S. D. at the 1-percent level .92

equivalent to 0.096 percent of organic matter in the plow layer. Applications of 32 tons of moist filter-press cake would be equivalent to twice as much organic matter. The decomposition of filter-press cake, like any other organic residue, must be rather rapid under the conditions of the Tropics. Therefore, in spite of the seemingly large additions of organic matter in the B and D treatments, as contrasted with the L treatments, the accumulated differences were not significant.

The mean C/N ratios were between 9.6 and 9.9 at Arecibo, and between 8.3 and 10.6 at Corozal. The differences were not significant. All these ratios considered together were rather narrow, which indicates that the filter-press cake decomposes rapidly under the action of the soil micro-organisms. No

wide C/N ratios indicative of slow decomposition, were observed. However, it must be remembered that the plots to which filter-press cake had been added received 1,500 pounds to the acre of a 12-6-10 fertilizer, which insured an adequate supply of nitrogen for both micro-organisms and plants during the early critical stages of crop growth.

Table 4 gives mean values for total exchange capacity; exchangeable calcium, magnesium, and manganese; and available phosphorus and iron for the soils from the Arecibo and Corozal experiments. The mean total exchange capacity of all the plots was 8.2 m.e. and 12.5 m.e. for the Arecibo and Corozal experiments, respectively, with very small deviations above or below.

The soils are very low in calcium (less than 25 percent) and magnesium saturation at both locations. In general, they are high in manganese and low in available phosphorus and iron. Under the conditions that prevail in Corozal, applications of 16 and 32 tons to the acre of filter-press cake increased the exchangeable calcium and magnesium and decreased the exchangeable manganese; but did not affect the available phosphorus and iron of the soil. At Arecibo, none of the elements considered were apparently affected.

As shown in table 5, the soils receiving filter-press cake-applications seemed to have a larger capacity to retain water at low tensions (pF 1.78) than the soils otherwise treated. This water is readily available and the plants can remove it quickly until tensions in the vicinity of the permanent wilting percentage (pF 4.2) develop. The retention of moisture at pF 4.2 tends to be lower in the plots treated with filter-press cake. Thus in all probability, they can supply more available water for crop growth than plots otherwise treated. Continued treatments over a period of years may result in larger accumulations of soil organic matter and consequently in greater moisture-supplying power. This may have a bearing upon crop yields. There were no outstanding differences in permeability, quick drainage, and maximum saturation in the soils of Corozal undergoing the various filter-press cake treatments.

Table 6 presents data on bulk density, total porosity, and air porosity of soils taken from the plots undergoing the various filter-press-cake treatments. Bulk-density values average 1.19 gm./cc., with very small deviations above or below. The mean porosity of all plots, irrespective of treatments, was 54.7. The air porosity was in inverse relationship to the water porosity (water retained at pF 1.78), the total pore space being more or less constant.

The results of these investigations are not conclusive by any means. It remains to be proved beyond doubt that the increased yields reported to be attributable to filter-press cake applications (1, 4, 5, 6, 7) are the reflection of the effect of the treatments upon soil conditions. The incorporation of

large quantities of organic matter in a continuous steady way for a number of years has been shown to produce a better state of aggregation and consequently the formation of a larger proportion of macroaggregates capable of holding considerable quantities of water at relatively low tensions. The

TABLE 5.—*Permeability and other soil-moisture data gathered from soil cores collected from the filter-press-cake experimental field at Corozal*

Treatment identification letter	Description of soil treatments		Permeability	Water drained at 60 cms. in 15 minutes	Maximum saturation	Water retained at pF of—			Available water (water at pF 1.78-water at pF 4.2)
	Filter-press cake	Fertilizer 12-6-10				1.78	2.7	4.2	
	Tons/acre	*Pounds/acre*	*Inches/hour*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B	16	1,500	12.9	8.1	54.9	40.0	35.4	23.5	16.5
D	32	1,500	22.7	8.1	53.7	39.6	32.2	24.5	15.1
L	0	3,000	32.4	12.6	55.8	36.3	33.6	26.2	10.1
L.S.D. at the 5-percent level			31.9	7.1	4.0	5.3	3.8	3.6	5.8
L.S.D. at the 1-percent level			45.8	10.2	5.8	7.5	5.0	5.1	8.3

TABLE 6.—*Bulk density, pore space, and air porosity of soils from the filter-press-cake experimental field at Corozal*

Treatment identification letter	Description of soil treatments		Bulk density	Total pore space	Air porosity (total pore space-water at pF 1.78)
	Filter-press cake	Fertilizer 12-6-10			
	Tons/acre	*Pounds/acre*	*Gm./cc.*	*Percent*	*Percent*
D	16	1,500	1.21	54.5	14.5
B	32	1,500	1.18	54.5	14.9
L	0	3,000	1.19	55.2	18.9
L.S.D. at the 5-percent level			0.07	2.4	7.1
L.S.D. at the 1-percent level			.10	3.5	10.1

work of Lugo-López, Landrau, and Samuels (8) with sugarcane trash substantiates this fact. Browning and Milán (3) have observed significant increases in aggregation with each unit increase in organic matter. Perhaps the influence of filter-press cake upon soil conditions can be measured in a clear-cut way after several years of continuous treatments.

In Puerto Rico the yearly production of filter-press cake has been estimated to fluctuate between 150,000 and 360,000 tons. The following tabulation indicates the extent to which filter-press cake was used in 1951.[5]

[5] Personal communication by Alcides Zeno, Chief, ACP and District Officer Di-

	Tons	*Benefit payment*
Filter-press cake applied to cane lands	136,211	$ 68,105
Filter-press cake applied to other lands	113,767	113,768
Total	249,978	$181,873

The benefit payments of the Production and Marketing Administration have greatly enhanced the use of filter-press cake on the farm. More than half of the filter-press cake obtained is applied to sugarcane fields, mostly new plantings. The rate of applications varies from 15 to almost 100 tons to the acre. However, with the large bulk of trash available in sugarcane fields there is hardly any need for additional organic-matter sources (8). The emphasis should be shifted towards applications of filter-press cake to other crops such as pineapple, truck crops, and so on.

SUMMARY

Data are presented here on soil conditions at the Arecibo and Corozal filter-press-cake experimental fields 18 months after establishing the treatment differentials. The experiments were located on a Bayamón silty clay and a Lares clay, respectively, both representative of the group of soils generally used for growing pineapples in the northern and interior districts of the Island.

A previous report indicated that maximum yields of pineapple in the Arecibo region could be obtained with applications of 1,500 pounds to the acre of a 12-6-10 fertilizer, if applications of filter-press cake were made at the rate of 32 tons to the acre. At Corozal, however, both heavy applications of filter-press cake (32 tons) and of fertilizer (3,000 pounds) were necessary for obtaining maximum yields.

Soil samples were taken from the top 6 inches at both locations and analyzed for pH, nitrogen, organic matter, total exchange capacity, exchangeable calcium, magnesium, and manganese, and available phosphorus and iron. In addition, undisturbed soil cores were taken at Corozal and data were gathered on the permeability, rapidity of drainage, maximum saturation, water retained at various tensions, porosity, and bulk density.

Although no significant differences were obtained in most cases, some trends were observed, such as the retention of larger quantities of available moisture at low tensions in a state of ready availability for plants by soils to which filter-press cake was added than by those to which only fertilizer was applied. The C/N ratios were narrow in all cases, indicative of quick decomposition of the organic residues after application.

vision, Production and Marketing Administration, U.S.D.A., to J. A. Bonnet, Head, Soils Department, Agricultural Experiment Station, University of Puerto Rico, Sept. 4, 1952.

RESUMEN

Se presentan aquí datos sobre las propiedades del suelo en los campos experimentales de Arecibo y Corozal 18 meses después de haber tratado parcelas con dos niveles de cachaza y haber dejado parcelas testigos sin recibir cachaza. Los experimentos se localizaron en suelos de Bayamón limoarcilloso y Lares arcilloso, ambos representativos de los suelos donde generalmente se cultiva la piña en las zonas norte e interior de la Isla. En un informe previo se presentó evidencia que indicaba que se podían obtener rendimientos máximos de piña en la zona de Arecibo con aplicaciones de 1,500 libras de abono 12–6–10 si se habían hecho aplicaciones de cachaza previamente a razón de 32 toneladas por acre. En Corozal, sin embargo, es necesario aplicar 32 toneladas de cachaza y 3,000 libras de abono por acre para poder lograr rendimientos máximos de piña.

En ambas localidades se tomaron muestras de las primeras pulgadas del suelo y se determinó el pH, contenido de nitrógeno, materia orgánica, capacidad total de intercambio, calcio, magnesio y manganeso intercambiable, y fósforo e hierro asimilables.

En Corozal se tomaron además, columnas de suelo en su estado natural y se midió la permeabilidad, agua removida en 15 minutos a una tensión de 60 centímetros, saturación máxima, humedad retenida a varias tensiones, porosidad y densidad aparente del suelo.

Aunque no se obtuvieron diferencias significativas atribuíbles a los tratamientos en la mayoría de los casos, se observaron tendencias de importancia, tales como mayor retención de humedad aprovechable en los suelos que recibieron aplicaciones de cachaza en contraste con los que sólo recibieron abono químico.

La razón de carbono a nitrógeno fué estrecha en todos los casos, indicando que la descomposición de la materia orgánica fué rápida.

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TERMITE-REPELLENT WOOD EXTRACTIVES[1]

George N. Wolcott[2]

INTRODUCTION

The basic food requirements of insects are substantially the same as those of vertebrate animals. This is true regardless of how innutritious or indigestible the food substance may seem to us, for from it the insect organism must necessarily extract carbohydrates essential for activity, and proteins essential for growth and development. Unless restricted by custom or habit to some one food, insects choose the more nutritious, and wood-eating insects choose the wood containing the most digestible nutrients.

Of the principal constituents of wood, lignin is entirely indigestible, and termites are almost unique in that the cellulose of wood becomes available to them because protozoans present in their alimentary tract can digest it. Upon the death of the protozoan, the cellulose is released and can be absorbed by the termite. But even though termites can thus assimilate more of the wood constituents than other wood-feeding insects, it cannot be clearly demonstrated that the dry-wood termites chose woods with a high cellulose content rather than those containing more lignin, or that this is one of the important "Factors in the Natural Resistance of Woods to Termite Attack" (1)[3].

Indeed, the sapwood of every wood tested without exception is somewhat to very much more acceptable than is the heartwood, yet chemical analyses of numerous woods indicate that there is little if any more cellulose in the sapwood than in the heartwood. The marked preference for sapwood so universally shown by dry-wood termites is due rather to the presence here of such constituents as sugar, starch, and proteins, in considerably greater quantity than in the heartwood. Physiologically, the heartwood of the tree is inert and dead tissue, primarily useful to the tree for mechanical support, and is eaten by dry-wood termites only when none of the more nutritious sapwood is available.

As all of these desirable nutrients are necessarily present in all woods, the marked preference of termites for some kinds of woods, and their avoidance of others, depend upon the presence of minute amounts of other constituents which are definitely toxic or repellent. Because most wood chemistry deals with the conifers and softwoods used in pulp and paper

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[3] Numbers in parentheses refer to Literature Cited, p. 227.

production, and because these constituents are present in such small amounts, surprisingly little is known about them. Indeed, their detection and separation by the chemist require also the contemporary cooperation of the entomologist to prove their toxicity, or to determine that they are sufficiently objectionable to the insects to account for the immunity of the wood from insect attack.

Until recently the only known such wood constituent was derived from East Indian teakwood, *Tectona grandis* L.: beta-methylanthraquinone, or "tectoquinone". We may possibly question whether tectoquinone is really the vitally important and essential constituent responsible for the well-known resistance of teakwood to rot, decay, and insect attack. Of the other quinones commercially available for test, none showed comparable repellent properties, and of tectoquinone itself, a concentration of at least 1-percent impregnated into flamboyán wood was required for permanent protection against dry-wood termite attack. By comparison with other comparable substances about to be mentioned this seems excessive.

EXPERIMENTAL FINDINGS

The wood of a Venezuelan tree locally called "ciezo" or "guaricamo", is not merely repellent to termites but so toxic that they die when confined with a small sample. The tree never attains a size to be used in construction or as a cabinet wood, but its extractive, called "ryanodine" by chemists in the research laboratories of Merck & Co., (2) is commercially used as an insecticide. It was first sold under the trade name "Ryanex," but is now processed and handled by S. B. Penick & Co., producers and manufacturers of other insecticides.

Ryanodine is soluble in acetone, and dilutions of one-fiftieth of 1 percent in which flamboyán samples were submerged for 10 minutes proved to be toxic to dry-wood termites for several weeks and prevented the attack of fresh termites for over 6 months. To date, 3 years later, similar samples impregnated with one-twentieth of 1 percent have not been eaten, and possibly this concentration will give permanent protection. Ryanodine has not been available for test as long as tectoquinone, but from these preliminary tests it appears to be approximately 20 times as effective against termites.

A short notice in Science mentioning the investigations being conducted by some of the smaller research institutions in Europe led to correspondence with Holger Erdtman, in charge of the Division of Organic Chemistry in the Royal Institute of Technology at Stockholm, Sweden. He was obtaining "heartwood extractives of conifers" (3) which had not been tested against termites, and indeed was experiencing the greatest difficulty in having them comparatively tested with any wood-eating insects. The minute

amount of pinosylvin (3,5-hydroxystilbene) extracted from the heartwood of Scotch pine which he sent for preliminary trial proved to be much more toxic to termites than any chemical previously tested, and at one-hundredth of 1-percent concentration has continued to protect the treated sample of flamboyán wood against termite attack for over 15 months.

We do not know, indeed, how effective pinosylvin really is, for no tests at greater dilutions have been made, this being the minimum dilution at which any other chemical has been able to protect wood for even a few days. Erdtman wrote: "Pinosylvin and its mono- and dimethyl ether appear to be characteristic components of the heartwood of almost all pine species. These stilbene derivatives appear to be characteristic components of the genus *Pinus*". To date these other constituents have shown as great a resistance to termite attack as pinosylvin itself. Even the commercially available stilbene, although eaten in 11 months at one-hundredth of 1 percent concentration, has continued repellent to date at one-fiftieth of 1 percent.

The extractives obtained by Erdtman from other species of conifers less resistant to insect attack than is Scotch pine do not protect against termites: a result which might well be anticipated even before the tests had been made. But chlorophorin, a modified pinosylvin with a long chain attached, extracted by him from the tropical tree "mora", *Chlorophora tinctoria* (L.) Gaud., although failing to protect treated flamboyán wood at one-hundredth of 1 percent concentration, to date is uneaten at one-fiftieth of 1 percent. Chlorophorin is a dull greenish-brown powder, even the greatest concentrations of which do not stain flamboyán wood, and should not be confused with the dye, morin, the much better-known product of mora, which has no insecticidal properties.

West Indian mohogany, *Swietenia mahagoni* Jacquin, is not only a most beautiful and desirable cabinet wood, but its especial value in the Tropics depends upon its well-known resistance to dry-wood termite attack. Until very recently no chemist has attempted to find out why it is resistant, and I am proud in being able to announce that Conrado F. Asenjo of the School of Medicine of the University of Puerto Rico, has not only started work, but has progressed in his investigation and has already separated the crude material containing the hitherto unknown extractive.

He found that 2-percent sodium hydroxide solution extracted over a tenth of the weight of the mahogany, and that water extracted over 2 percent, but flamboyán samples submerged in these extractives were as attractive to dry-wood termites as if untreated. The extractives from mahogany obtained by hydrochloric acid and by acetone were only slightly less attractive, and obviously they did not contain the particular chemical which is the basis of the ability of mahogany to withstand dry-wood termite attack. All of these extractives were more or less purplish-brown, but this stain

was not noticeable in the treated flamboyán wood. When the termites fed on these samples, however, the contents of their abdomens turned purple: as conspicuous an indication of what they had been eating as blackberry jam smeared around a small boy's mouth.

Ether petroleum extracted none of this purplish dye from mahogany, but its extractive was light yellowish in color, precipitating on standing a waxy white substance, which, at one-twentieth of 1 percent concentration entirely protected flamboyán wood from termite attack. Asenjo has thus obtained the vitally important extractive from mahogany; it still remains to ascertain whether this is one substance, or a mixture of several, and also to determine their chemical composition and properties.

SUMMARY

Neither hardness nor high lignin content of a wood prevent its being eaten by dry-wood termites. Immunity from attack of so-called termite-resistant woods is due to the presence of some specific chemical constituent, such as tectoquinone in East Indian teak, in comparatively small amounts which causes it to be toxic or unpalatable to the insects. This substance extracted from the wood may be used as an insecticide, like commercial Ryania from *Ryania speciosa*, or for impregnating termite-susceptible woods to make them immune to termite attack. Conrado Asenjo of the local School of Medicine is working on the extractives of West Indian mahogany.

RESUMEN

Ni la dureza, ni el alto contenido de lignina de una madera evita que ésta pueda ser atacada por la polilla. La inmunidad de las llamadas maderas resistentes a la polilla proviene de algún constituyente químico específico, que hallándose comparativamente en pequeñas cantidades en ciertas maderas, las hace tóxicas, o por lo menos indeseables a los insectos. Un ejemplo puede ser la tectoquinona que se encuentra en la teca de la India Oriental.

Estas substancias, extraídas de la madera, pueden usarse como insecticidas, según se hace con la Ryania, la cual se origina de la *Ryania speciosa*. También pueden usarse para impregnar maderas susceptibles a la polilla para inmunizarlas contra los ataques de este insecto.

El Conrado Asenjo, de la Escuela de Medicina, se ha venido ocupando últimamente en extraer estas substancias de la caoba antillana.

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BIOLOGICAL CONTROL OF THE PUSTULE SCALE IN PUERTO RICO

George N. Wolcott[1]

INTRODUCTION

Total disappearance of an insect pest from a region over a series of years, giving the appearance of extermination, may result from the perfection of biological control. Such temporary elimination may indeed prove permanent, presumably because of natural control by parasites and predators already present and endemic as in the case of the cotton leafworm, *Alabama argillacea* Hübner. From 1942 to 1949 it did not appear in Puerto Rico at all in any part of the Island (1)[2], and cotton growers and members of the cotton cooperative began to wonder what to do with their stocks of arsenate of lead accumulated in anticipation of outbreaks that did not occur.

But the cotton leafworm is really unique and hardly comparable to any other insect. Its moths fly in from adjacent islands to start an infestation which may quickly develop into widespread outbreaks extending from one side of the Island to the other and continuing indefinitely because of the local two-season system of cotton growing. For lack of fresh fields to attack, or because of excessive parasitism, or an impulse to migrate affecting all the moths of the final generation, the insect may have disappeared for good. We can be the more certain of its absence here because the caterpillars feed only on cotton leaves, and growers are vociferous in their complaints if any small field anywhere is attacked. Entomologists in Venezuela report that the leaves of a wild cotton, *Cienfugosia affinis* (H.B.K.) Hochr. (= *Hibiscus sulphureus*), a common weed in burned-over regions and abandoned fields, serve as alternate host for the caterpillars, but this plant does not occur in Puerto Rico.

The enormous numbers of the introduced giant Surinam toad, *Bufo marinus* Linnaeus, which developed in Puerto Rico within a few years from the few individuals sent from Barbados in 1920, and from those brought from Jamaica 2 years later had a more profound effect on some of the insects and other small invertebrates of the Island than any other addition to the local fauna in historic times (2). One must not suppose, however, that the numbers of all the endemic species of May beetles were reduced

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[2] Numbers in parentheses refer to Literature Cited, p. 233.

to the vanishing point, for those which occur only at the higher elevations where the minimum temperatures are too low for the permanent presence of the toad, were unaffected.

Walter Jepson, who attempted the first introduction of *Bufo marinus* into Mauritius, tells me that the toads there, although thriving during warm weather when they first arrived, found the winter temperatures too cold for their continued existence even along the coast. Along the coast of Puerto Rico where most of the sugarcane in grown, the temperatures proved to be optimum for the development of the toad, and control of white grubs in cane fields was total for 12 or 15 years. The very perfection of white grub elimination by the toad proved to be the reason it could not be permanent.

Despite the considerable number of other insects and small animals such as millipedes which could serve to supplement the maybeetles[3] as major items in the food of the toad, millions of the toads perished from starvation when all of these ceased to exist in appreciable numbers. Indeed, so few toads survived as to present an opportunity for all of the insects and other small animals eaten by toads again to begin increasing in numbers, at least temporarily unchecked by *Bufo*. It was by far the most conspicuous local example of the principles of biological control: temporarily so successful as to make its subsequent failure all the more distressing, and the necessity for the eventual use of chemical insecticides imperative.

CONTROL AND REAPPEARANCE OF PUSTULE SCALE

The purpose of the present paper is to present still another instance of the merely temporary effectiveness of biological control. The pustule scale, *Asterolecanium pustulans*, originally described from Jamaica in 1892 by T. D. A. Cockerell (3), was collected in Puerto Rico in 1900 by Augustus Busck (4). It attacks no economic crop, but it has been under more or less continuous observation by entomologists, and we have numerous records of its occurrence and abundance (1). Indeed, to it may be ascribed the practical disappearance of the Australian silver oak, *Grevillea robusta* Cunn. after it had been introduced and extensively planted, some 20 years ago.

Especially noticeable in 1939–40 were outbreaks on maga, *Montezuma speciosissima* Sessé & Moc., an endemic tree with wood even more highly valued by the cabinetmaker than mahogany. A few years earlier the local Forest Service had introduced *Sciacassia siamea* (Lam.) Britton, a very rapidly growing tree, of which rapid growth was almost the only valuable characteristic. The pustule scale attacked it with such deadly effect that

[3] Although Dr. Wolcott prefers the spelling "May beetle", the January 1953 Edition of the U. S. Government Printing Office Style Manual, which is followed in editing, prescribes "maybeetle."

trees 6 and 8 inches in diameter were killed down to the ground. The pustules on tender shoots of oleander, *Nerium oleander* L., were especially large and distorting, and were omnipresent on this host everywhere up to 1940.

When Louise M. Russell visited Puerto Rico in the spring of 1952, every effort was made to find specimens on oleander, for her major publication is "A Classification of the Scale Insect Genus *Asterolecanium*" (5). Despite persistent search, no specimen of the scale could be found. If pustule scale had formerly been a rare or inconspicuous insect, such a result might have been anticipated, but on the contrary, it previously had been common, and the injury it caused was very conspicuous. The leaves of maga on branches killed by the pustule scale turn brown and adhere en masse, at a distance resembling the symptoms of fire blight on apple or pear, and forming extensive brown areas on roadside trees that can be readily noted without even stopping the car.

Consulting our records, the last observation was at Guanica in 1941, by Luis F. Martorell on *Colubrina ferruginosa* Brongn. On mass infestations collected before that time, many scales were noted with parasite emergence holes, presumably of the endemic *Mercetiella reticulata* and *Euaphycus portoricensis* described by H. L. Dozier (6). These parasites were unquestionably present in Puerto Rico long before they were reared and described, but up to this time had never exerted more than partial control. Some other factor must have been operating to cause the disappearance of the pustule scale in the subsequent 12 years.

In the early days of citrus growing in Puerto Rico, before oil sprays for the control of scale insects had been discovered by W. W. Yothers in Florida, almost the only measure that the grower could take to try to prevent heavy scale-insect infestation was to favor entomogenous fungi by planting windbreaks. Those of common bamboo, *Bambusa vulgaris* L., were almost invariably heavily infested with scale insects, *Asterolecanium bambusae* Boisduval and *A. militaris* Boisduval, but as these scales did not spread to the citrus trees and appeared to have little effect on the growth of the bamboos, nobody gave them serious attention.

When Atherton Lee was appointed Director of the Federal Experiment Station at Mayagüez, he had just returned from a tour of duty in the Philippines and the Orient, where the bamboo is economically much more important than in Puerto Rico. Convinced that something should be done about its heavy scale infestations, he was instrumental in having predaceous ladybeetles imported to prey upon them. In the Mayagüez region several of these imported ladybeetles are reported to be "firmly established", but the only one almost invariably present on bamboo elsewhere on the Island, and definitely and consistently feeding on the scale insects of bamboo, is

a large, bright-yellow ladybeetle with iridescent green elytra: *Cladis nitidula* Fabricius.

Despite this new factor in their environment, the bamboo scales appear to be quite as abundant as formerly, the rapidity of reproduction of the beetle and its natural control by lizards being so well adjusted to the rapidity of reproduction of the scale insects that they are in perfect balance. Sometimes venturesome ladybeetles abandon bamboo and are noted eliminating infestations of quite different kinds of scale insects on other hosts. But one can always find them abundant on the clump of bamboos near the old Río Piedras reservoir, which appears to be a permanent sanctuary for them.

Much the most adventurous and venturesome of these introduced ladybeetles in *Chilocorus cacti* Linnaeus, all black in color except for a crimson spot on each elytron. It will feed on the scale insects of bamboo, but is preferably almost omnivorous on many other kinds of scale insects on numerous hosts. It was one of the "Introduced Ladybeetles on Mona Island" which apparently invaded Mona without the intervention of man, and was observed there in the spring of 1944, when it had cleaned up scale-insect infestations on several hosts so recently that the outlines of the scales could still be seen on the host plants (7). The single record of the twice-stabbed ladybeetle eating the scales of *Asterolecanium pustulans* was at Guanica in 1941, but the time when *Chilocorus cacti* was most abundant here synchronized closely with the practical disappearance of several other scales, especially those on papaya.

The growing of papayas is hardly on a large commercial scale as yet, but numerous plantings have been made in recent years. Most surprisingly, scale-insect infestations rarely develop in these plantations, in very marked contrast to the rapid inevitability of infestation on papaya plants before *Chilocorus cacti* was brought to Puerto Rico. Two scale insects attack papaya in the West Indies: the grey scale, *Pseudoparlatoria ostreata* Cockerell, and the white scale, *Pseudalacaspis pentagona* Targioni. The latter is historically known as the "West Indian peach scale", and in the Kenscoff region of the mountains of Haiti it was a major pest on peach trees, as well as on papayas at lower elevations. Lizards inhabiting every tree and post of the coastal areas are important limiting factors on the abundance of ladybeetles, especially when they rest on the naked trunks of papayas. But there are no arboreal lizards in the high mountains of Haiti and *Chilocorus cacti* practically eliminated West Indian peach scale on peaches there (8). A year later, every remaining infestation had disappeared, and at least local extermination of *Pseudalacaspis pentagona* was an accomplished fact.

Even to approach such control of the same insect on papayas in Puerto

Rico is a slower and much more uncertain process because of the omnipresence of lizards. Several personal experiences in attempting to bring ladybeetles from the papaya grove at Isabela Substation to the metropolitan area of San Juan, and having a lizard rapidly devour beetle after beetle before they could get adjusted to a similar environment in a new locality, all too clearly indicated the hazards attendant on the life of a black ladybeetle attempting to be inconspicuous on the naked white trunk of a papaya. Fortunately, the gregarious larvae are much less obvious; they move like a tidal wave engulfing a mass infestation of scale insects. Slowly but inevitably every scale is devoured. The final result is so close to extermination of both species of scale insects on papaya that one can rarely find them at all on new plantings being made. If growers are spraying at all, it is with DDT to control the leafhopper transmitting bunchy-top disease.

Chilocorus cacti feeds by preference on other scales than on those on bamboo, but it not only can, but does eat those species of *Asterolecanium* on bamboo when other sources of food fail. However, it greatly prefers *Asterolecanium pustulans*. The last record of this scale before its disappearance was of being eaten by the twice-stabbed ladybeetle, and so also the first record of its reappearance: in 1935 at Vega Baja on oleander, with numerous empty craters which the ladybeetles had just emptied of their insect contents.

In the absence of pustule scales to attack oleander, this ornamental recently has become almost universally infested with a whitish scale insect, identified by Harold Morrison as *Aonidiella orientalis* (Newstead) "for many years reported as *A. cocotiphagus* Harl.", and this scale insect is apparently not being eaten at all by the twice-stabbed ladybeetle. Such surprising specificity in its choice of food by *Chilocorus cacti* has thus allowed one formerly none too common scale insect to become omnipresent on oleander at the same time that for 12 years it kept this host entirely free of pustule scale.

SUMMARY

The perfection of biological control results in only apparent extermination for a period of years. The pustule scale, *Asterolecanium pustulans* Cockerell, so eagerly eaten by the introduced twice-stabbed ladybeetle, *Chilocorus cacti* Linnaeus, as to result in its complete disappearance, appeared again in Puerto Rico after 12 years.

RESUMEN

La excelencia del control biológico resulta sólo en una aparente exterminación del insecto dañino por un período de años. La cochinilla pustulosa, *Asterolecanium pustulans* Cockerell, tan ávidamente engullida por la coto-

rrita, *Chilocorus cacti* Linnaeus, importadó para ese fin, desapareció completamente para luego surgir después de 12 años.

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CONTROL OF THE LAUREL THRIPS, *GYNAIKOTHRIPS FICORUM* MARCHAL

George N. Wolcott[1]

INTRODUCTION

The density of evergreen foliage of *Ficus nitida* Thumb., "laurel de la India," as it is called in Puerto Rico, or the "India laurel fig" of Florida nurserymen, with its small, waxy, shining leaves, oval but pointed at both ends, has caused its selection for shading the plaza or promenade of many a tropical city. The most serious objection to laurel is its susceptibility to mass infestations of the tropicosmopolitan thrips originally described (1)[2] by P. Marchal as *Phloethrips ficorum* from Algeria, but now present by accidental introduction in such widely separated localities as Java, Guam, the Canary Islands, southern Florida, Cuba, Hispaniola, and Puerto Rico.

The feeding of the adult thrips on the tender light-green leaf is initially marked by sunken reddish spots along the midrib, but the tight curling of the leaf is caused by the development of colonies in the immature stages. As the nymphs mature, the tightly curled leaf becomes hard and tough, then gradually yellower and browner, and adheres less tightly to the twig, so that thousands may drop at the first heavy rain after an extended period of dry weather, covering sidewalks and pavements with unsightly windrows of debris. The thrips ordinarily do not attack other vegetation, and indeed most species of *Ficus* are largely or entirely immune to infestation, but when they become abundant on their specific and preferred host, they tend to cause defoliation of all the new leaves on the outside of the tree. (Fig. 1.)

The thrips do not intentionally bite people, but they are a terrific nuisance to people resting or promenading underneath infested laurels, getting in the eyes, or entangled in the hair, and ticking the skin as they attempt to escape. Students of the University of Puerto Rico, attempting to study on the benches or in cars parked under the laurel trees that have been so universally planted for the adornment of the campus, find these little hard black insects dropping from the trees very annoying.

CONTROL

The availability of a single, moderate-sized laurel de la India tree, comparatively isolated on the grounds of the Agricultural Experiment Station at Río Piedras, has made possible experiments in the control of this thrips. Preliminary tests with 1-percent and 0.5-percent Aldrin on part of another

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[2] Numbers in parentheses refer to Literature Cited, p. 240.

tree indicated that all thrips were promptly killed by spraying, and the experiment proper was commenced, using Aldrin at 0.25-percent concentration on March 18, 1950. This was also effective, but few thrips were

FIG. 1.—Twig of *Ficus nitida*, showing thrips-distorted leaves and partial defoliation caused by thrips infestation. (Original)

killed by a subsequent spraying at a dilution of 0.125-percent, and spraying had to be promptly repeated when 0.25-percent was used. Despite the tight curling of the leaves all thrips succumbed to the spray, so that within a few hours after treatment, only dead ones could be found. The comparative isolation of the tree did not prevent reinfestation from unsprayed trees

a few hundred yards away. Residual effect did not protect fresh foliage, and the tree had to be sprayed at intervals of 1½ to 2 months, as soon as adults were noted in any curled leaves. Applications of Dieldrin were alternated with those of Aldrin, with no appreciable difference in the results. (Fig. 2.)

When inhabited by colonies of live thrips: Eggs, nymphs, and adults, the curled leaves rarely shelter other animals except those predaceous upon them: Anthocorid bugs, *Macrotracheliella laevis* Champion and *Cardiastethus rugicollis* Champion reported by Dr. H. L. Dozier (2), besides

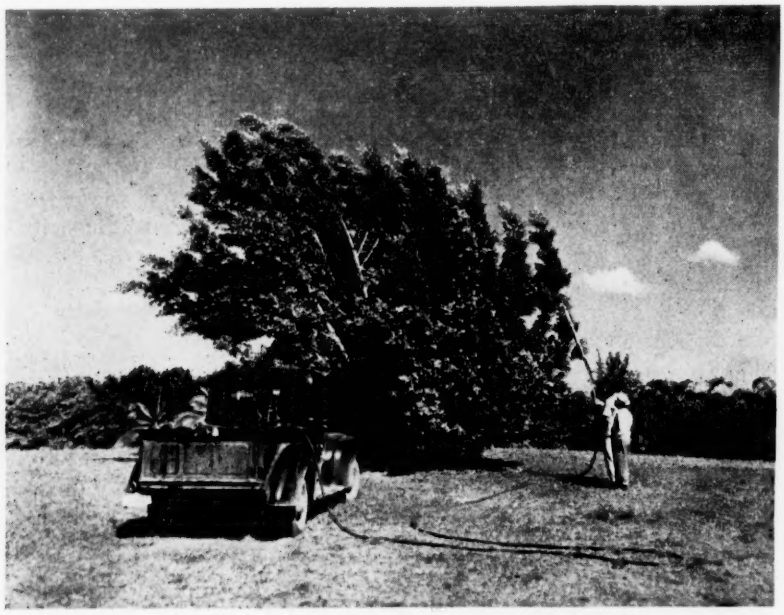

FIG. 2.—Spraying an isolated laurel de la India tree at Río Piedras. (Original.)

orange-colored Dipterous maggots and small ladybeetle larvae. When the thrips have been killed, the curled leaves conceal scale insects such as *Ischnaspis longirostris* Signoret, the black thread scale, or the "Florida red" scale, *Chrysomphalus aonidum* Linnaeus (= *ficus* Ashmead), as well as mites presumably feeding on the dead thrips, and various spiders. Such curled leaves, no longer being injured by the thrips, remain green and as tightly adherent to twigs as normal leaves. They do not fall, and continue as part of the evergreen foliage, despite their initial malformation, but become less conspicuous as fresh growth develops.

Six months after spraying began, many of the originally curled leaves were still present on the tree, despite increasingly heavy scale-insect infestation within. As the experiment continued, it became apparent that to

eliminate the curled leaves entirely, applications would have to be made as often as a month apart if all distortion of the fresh leaves was to be prevented. Indeed, waiting until a fresh infestation developed before admistering the next spray proved to be the wrong approach if complete protection was to be obtained. Considerable injury developed with great rapidity if spraying were at all delayed, and psychologically the month-and-a-half interval proved difficult. Thus the recommendations for control would be spraying with 0.25-per cent Aldrin at monthly intervals as a permanent routine throughout the year, to be continued for the life of the tree.

REPLACEMENT OF SUSCEPTIBLE WITH THRIPS-IMMUNE SPECIES

If this continuous round of spraying seems a high price to pay for freedom from thrips injury on laurel trees, it might be suggested that another alternative is replacing the *Ficus nitida* trees with other species of *Ficus* that are apparently entirely immune to thrips infestation. Close to the laurel tree used in the experiment was one which has been identified as *F. benjamina* Linnaeus. Its leaves are longer and more pointed at the ends, somewhat more widely spaced apart, but it has a similar dense foliage, and if it seems to have a more drooping natural habit of growth, this should be readily cured by pruning. Its berries are large and abundant, and when ripe, as bright a red as those of holly, although not as shining. Even during the dryest weather over a series of years no thrips infestation has been observed on this tree, and it seems equally free of the scale insects that often attack *F. nitida*. Entomologically, it is a desert, and in consequence, ever so much more desirable to the general public. (Fig. 3.)

Merely because all observed trees of *F. benjamina* in Puerto Rico are free of thrips infestation, one should not conclude that what appears to be this tree elsewhere is immune to thrips. Nothing could be further from the fact. Those lining the Avenida Independencia of the capitol city of the Dominican Republic are very heavily infested, as well as those in San Pedro de Macorís. D. C. Wolfenbarger (3) reported a severe infestation on a large tree growing in the Subtropical Experiment Station species block at Homestead, Fla., the thrips being identified by J. R. Watson as *Gynaikothrips uzeli* (Zimmerman), now considered a synonym of *G. ficorum* (Marchal).

J. Douglas Hood of Cornell University wrote under date of April 11, 1952: "The *Ficus* thrips seem all to be our old friend *ficorum*, and I do not understand it. The other workers, all foreign, have found the species of *Ficus benjamina* constantly to be *uzeli*." Hood had fresh material from the Dominican Republic and from Homestead, Fla.

H. von Oettingen of Eisleben, Germany, examining material collected from the same tree, supposed to be *F. benjamina*, at Homestead, and from *F. nitida* at the charter airport at Miami, found no difference in color, and

but minor difference in size of the thrips from the two hosts: "Immerhin sind diese morphologischen Unterschiede vorläufig noch zu gering, um mit Recht von einer besondered Rasse sprechen zu können. Zur Zeit kann man also nur von der Entstehung zweier biologische Rassen sprechen, deren morphologische Unterscheidenur schwach angedeutet sind."

Kellie O'Neill (Miss) of the U. S. National Museum, with a much more extensive series from additional hosts and many countries, found even

FIG. 3.—Twig of *Ficus benjamina*, showing fruit and foliage free of thrips injury. (Original.)

greater variations in size that were noted by von Oettingen, but with no consistent pattern based on host selection: "I find that specimens from all localities are smaller from *F. benjamina* than from *F. nitida*, but the range in size is larger than that given by Prof. von Oettingen in every case, so that there is a greater overlap between the ranges. Puerto Rican specimens are generally smaller than Florida specimens, those from *F. benjamina* in Florida being scarcely smaller than those from *F. nitida* in Puerto Rico. Specimens from other hosts either were intermediate in size with a wide range, as in those from *F. indica*, and from *Eucalyptus* in Cuba, or were larger than specimens from *F. nitida*, with individuals still coming within the upper limits of the figures given by Prof. von Oettingen for those from *F. benjamina*. Hosts of the series of larger specimens were *Gliricidia* from Puerto

Rico, 'sapote' from Colombia and citrus from Florida. It is my impression that *Gynaikothrips* may find *F. nitida* a better host that *F. benjamina*."

DISCUSSION

From the evidence produced by the studies of three specialists in Thysanoptera it must be concluded that but a single species of thrips is concerned. If two species actually exist, they certainly cannot be separated by any conspicuous and well-defined morphological character, but only on the basis of host selection.

It seems more probable that the key to the solution of this problem lies in the specific identity of the hosts. This assumes that the thrips-infested trees in the Dominican Republic, which superficially appear to be the same as what has been identified from Puerto Rico as *F. benjamina*, in reality are some other species. The single thrips-infested tree at Homestead supposed to be *F. benjamina*, certainly is not typical if the thrips-free *benjamina* trees in Puerto Rico and at the Miami Airport are used as a basis for comparison. Nor is the adjacent thrips-free tree at Homestead, identified as *F. retusa* Linnaeus (of which *F. nitida* is by some authorities considered a synonym), typical of the *F. nitida* trees at Miami, or in the Dominican Republic and in Puerto Rico. If these two trees at Homestead are not of another species, this assumption is certainly indicated by the thrips in their avoidance of one and choice of the other.

Insects are more directly concerned with the inherent differences in species of plants than are the systematic botanists, for their living depends ever so much more directly upon the preferential selection of a host most suitable for their nourishment. It may be presumed that the thrips-immune species of *Ficus* contain in minute amount some essential constituent, toxic or repellent to thrips, which is present in much smaller amount, or not at all, in the leaves of *F. nitida*. We may take advantage of such a clear-cut distinction made by the thrips, and, for the replacement of *F. nitida*, chose cuttings taken from trees the leaves of which are invariably and at all times of year free of thrips infestation.

SUMMARY

The laurel thrips, *Gynaikothrips ficorum* (Marchal), may be controlled by spraying at monthly intervals with 0.25-percent solution of Aldrin or Dieldrin. Or trees of its preferred host, "laurel de la India," *Ficus nitida* Thumb., may be replaced with quite similar species of *Ficus* which have been proved to be immune to thrips attack.

RESUMEN

El trips del laurel, *Gynaikothrips ficorum* (Marchal), puede controlarse por medio de aspersiones de Aldrín o Dieldrin al 0.25 por ciento, una vez al mes. Otra alternativa sería substituir el laurel de la India, *Ficus nitida*

Thumb., árbol hospedero preferido por el trips, por otros similares de la especie *Ficus*, los cuales han demostrado ser inmunes a los ataques de este tisanóptero.

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THE FOOD OF THE MONGOOSE (*HERPESTES JAVANICUS AUROPUNCTATUS* HODGSON) IN ST. CROIX AND PUERTO RICO[1]

George N. Wolcott[2]

INTRODUCTION

The mongoose has been receiving so much unfavorable publicity recently that any apparently beneficial aspects of its presence in Puerto Rico should be made known. One may wonder how it manages to capture and swallow a centipede, and admire its courage in attacking a tarantula, or speculate on how it finds so many of these animals to devour, but recent examination of the stomach contents of 98 freshly killed individuals indicates that centipedes and tarantulas form an important part of its food.

G. A. Seaman, Wildlife Supervisor of the Virgin Islands, shot 42 of *Herpestes javanicus auropunctatus* Hodgson in St. Croix during the past year and submitted the stomach contents for critical examination as to the insect remains present. David Pimentel of the U. S. Public Health Service has aided in the examination of 56 specimens caught mostly at Roosevelt Roads, Puerto Rico, during the summer and autumn of 1952. As a result of these observations, it appears that the mongoose eats very much the same items of food in St. Croix as in Puerto Rico: Mostly lizards, rarely a mouse or rat, a bullfrog or culebrita (blind-snake), but centipedes and tarantulas almost as often as lizards. Most of the insects it eats are Orthoptera: Wild cockroaches (not the ones found in houses), tree crickets, cave crickets, and ground crickets, besides both brown and green grasshoppers. Because it eats so many lizards, it may be presumed that some, or indeed most of the other insects found in the stomach of the mongoose when the remains of a lizard are also present, were originally eaten by the lizard. Houseflies and ants may have been eaten incidentally because they were present on the fish bait used to attract the mongoose, and should not be considered part of its normal food.

The problem of determining what the mongoose eats in nature is complicated by the fact that it quite thoroughly chews its food before swallowing, and that digestion of the comminuted food particles is rapid after entering the stomach. This is in very decided contrast to the feeding habits of lizards

[1] Extemporaneously presented at the annual meeting of the American Society of Agricultural Sciences held at Río Piedras, Puerto Rico, November 13, 1952, entitled "The Mongoose Eats Centipedes and Tarantulas."

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(1)[3], toads (2 and 3), and frogs (4), which swallow their food whole. Entire insects may be recovered intact and in such perfect condition that several species of Puerto Rican thrips (5) were described from material first collected in the stomachs of lizards.

Previous attempts to determine what the mongoose eats in Puerto Rico were failures, all the stomachs sent by Thos. H. Jones to the Bureau of Biological Survey in 1912 having proved to be empty. If the mongoose is caught in a trap visited only once or twice a day, digestion usually will have been so complete by the time the animal is dissected that nothing remains in the stomach for examination. It is quite essential, therefore, that the animals attracted to a bait in the field be shot and dissected immediately. My associate, Luis F. Martorell, tells me that he and other boys in Yabucoa used to shoot those attracted by the peeping of a baby chick separated from the mother hen, but this was merely sport, and no observations on stomach contents were made by him at this early stage of his scientific career. If the mongoose has already begun to eat of the bait at the time that it is killed, and a quantitative estimate is desired, such remains of fish vertebrae and flesh should be subtracted from what is found in the stomach, even though already thoroughly mixed with the comminuted remains of what had previously been eaten.

ITEMS IDENTIFIED FROM MONGOOSE ALIMENTARY TRACTS

Qualitatively, the identification of the various items of the stomach contents is by no means simple and specific determinations must often be largely a matter of conjecture based on the known fauna of the area inhabited by the mongoose. Yet in one instance, half the tarsal claw of a maybeetle[4] authenticated the species, although all other remains, including even the heavily chitinized elytra and prothorax, had been eliminated. Thus the following detailed list of items found is given with the caution that while presumably exact for the common animals recorded, some puzzling fragments found but once or twice may not have been correctly identified.

Items identified from the alimentary tracts of the Mongoose, Herpestes javanicus auropunctatus *Hodgson*, *42 from St. Croix, 56 from Puerto Rico*

Vertebrates:

3 masses of hair of mongoose	identified by
3 masses of hair of rat	Mr. Seaman or
2 masses of hair of mouse	Dr. Pimentel
1 introduced bullfrog, *Rana catesbeiana* Shaw	

[3] Numbers in parentheses refer to Literature Cited, p. 247.

[4] Although Dr. Wolcott prefers the form "May beetle," the January 1953 Edition of the U. S. Government Printing Office Style Manual, which is followed in editing this *Journal*, prescribes the form "maybeetle," presumably on the advice of a consensus of State and Federal entomologists. Ed.

2 treetoads or "coquís", *Eleutherodactylus auriculatus* Cope
2 blind-snakes or "culebritas", *Typhlops lumbricalis* Linnaeus
46 lizards, mostly *Anolis cristatelus* Duméril and Bibron
some *Anolis pulchellus* Duméril and Bibron, *Ameiva exsul* Cope
possibly other species also

Invertebrates:

1 fiddler crab from beach at St. Croix, reported by Mr. Seaman
4 land crabs or "jueyes", *Cardisome guanhumi* Latreille
1 beach flea, *Orchestia platensis* Kroger, from beach at St. Croix
38 centipedes, *Scolopendra subspinipes* Leach
3 small unidentified spiders
2 large spiders or tarantulas from St. Croix, (?)*Cyrtopholis bartholomei*
14 tarantulas, *Cyrtopholis portoricae* Chamberlin
1 daddy longlegs

Insects:

4 earwigs, *Labia curvicauda* Motschler
37 (or more) cockroaches, 9 or more *Pycnoscelus surinamensis* Linnaeus
1 *Epilampra wheeleri* Rehn, 1 the green *Panchlora cubensis* Saussure,
1 *Eurycotis improcera* Rehn, from St. Croix
other unidentified to species
24 large yellow-brown short-horned grasshoppers, *Schistocerca americana* Thunberg
18 large green (or red) katydids or long-horned grasshoppers, *Neoconocephalus triops* Linnaeus
46 crickets:
15 *Orocharis vaginalis* Saussure
9 *Ablona* (or *Gryllacris*) *guadeloupensis* Karny, from St. Croix
13 cave crickets, *Amphiacusta caraibea* Saussure
9 ground crickets, *Acheta assimilis* Fabricius
1 damselfly, *Lestes forficula* Rambur
1 cicada, *Proarna hilaris* Germar
2 chinchbugs, *Blissus leucopterus* Say
2 stinkbugs, *Euschistus bifibulus* PB
1 Carabid beetle, *Calosoma alternans* Fabricius
1 small Bostrychid beetle
2 fragments of elytra of small unidentified beetles
1 elytron of *Ligyrus cuniculus* Fabricius, from St. Croix
1 head of white grub, (?)*Phyllophaga microphylla* Moser, from St. Croix
2 female maybeetles, *Phyllophaga portoricensis* Smyth
½ tarsal claw of maybeetle, *Phyllophaga portoricensis* Smyth
1 bean Chrysomelid beetle, *Cerotoma ruficornis* Olivier (entire, probably caught originally by lizard)
4 leaf weevils, *Diaprepes abbreviatus* Linnaeus
1 Stratyomyid fly, *Neorondania chalybea* Wiedemann
1 blowfly, *Callitroga hominivorax* Coquerel, probably from fish bait
4 adults and 2 maggots of the housefly, *Musca domestica* Linnaeus
1 Anthomyid fly, *Fannia pusio* Wiedemann
1 Calobatid fly, *Taeniaptera lasciva* Fabricius
many very small flies, probably from fish bait

1 adult and 1 caterpillar of Hesperiid butterfly
1 small parasitic wasp, wing only

Ants

12 "berraco", *Odontomachus haematoda* Linnaeus (heads or entire ants)
1 *Monomorium* sp.
7 "hormiga brava", *Solenopsis geminata* Fabricius
10 *Pheidole megacephala* Fabricius
2 "albaricoque", *Tapinoma melanocephala* Fabricius
2 "hormiga loca", *Paratrechina longicornis* Latreille

EVALUATION

In attempting to appraise the impact of the mongoose on its environment as it affects the interests of man, one finds that too little is known regarding the food habits of some of the animals eaten. Those of the lizards of Puerto Rico are, however, well known. As predators on insects, their value is so obvious generally, and is so apparent to even casual observation, that one must forgive their interest in brightly colored and conspicuous ladybeetles. Many ladybeetles have an offensive odor (or at least an odor offensive to man) and it has been claimed that their bright warning colors prevent birds from eating them a second time.

Unfortunately for this theory, lizards swallow any moving object that looks like food, even the prickly, hairy woolly-bear caterpillars of *Ecpantheria icasia* Cramer, and so quickly that they never taste what they swallow, but merely react with apparent pleasure and satisfaction to the struggles of their living food as it goes down. Instead of being repelled by bright colors, they may swallow bright-colored berries and even eat immobile scale insects that are the shape and size of ladybeetles. Before the introduced Surinam giant toad had minimized the maybeetle population of Puerto Rico, even these exclusively nocturnal insects were eaten by the diurnal crested lizard. The ground lizard or "iguana", *Ameiva exsul* Cope, which appears above ground only during the middle of the day, burrows rapidly through the soil and eats the eggs of maybeetles and the white grubs that hatch from them. Thus, although lizards may destroy some beneficial insects, the bulk of what they eat are either neutral insects, or those definitely deleterious to man's welfare.

The Hispaniolan tarantula, *Phormictopus cancerides* Latreille, has been kept alive for long periods on captivity when fed principally on cockroaches and lizards. Jorge J. Serrallés kept one female for 12 years, for which he always brought back a mate when returning from Santo Domingo. The fate of the male was always the same, however; he was murdered within a few days and his skin sucked dry and rolled into a pellet by the female. Luis F. Martorell kept a female for 8 years which molted regularly during March or April,

and was fed principally the lizards which managed to penetrate the tightly screened insectary.

Of the Puerto Rican tarantula, *Cyrtopholis portoricae* Chamberlin, Alexander Petrunkevitch (6) says that "at the mouth of the burrow one may commonly see remains of large millipedes, constituting the chief food of these spiders." This observation, entirely correct at the time it was made, no longer applies to present conditions in Puerto Rico, for the imported giant toad has nearly eliminated millipedes locally. Years ago, more than one elytron and prothorax of maybeetles was noted at the entrance of holes in the ground presumably made either by the tarantula or the centipede, but maybeetles are no longer sufficiently abundant in Puerto Rico to serve as a dependable source of food every year and at all times of year for either toad, tarantula, or centipede.

Indeed, one can but wonder what tarantulas and centipedes do find to eat in any abundance since the advent of the toad, for their holes seem to be quite as numerous now as at any time in the past. If one considers these animals as merely ugly, nocturnal, and potentially dangerous creatures liable to attack man, the role of the mongoose in destroying them can be regarded as entirely beneficial. From another more basic point of view extensive destruction of centipedes and tarantulas may be to some extent, or even largely, against the best interests of man. Of this we cannot judge, however, without determining the main items in their food at the present time.

No records exist of outbreaks of grasshoppers in Puerto Rico, at all comparable to those in other countries, before the introduction of the mongoose here. Indeed it is very doubtful whether the comparative scarcity of grasshoppers and katydids in Puerto Rico is due, except to a very minute extent, to their being eaten by the mongoose. Never having been economic pests here, they can hardly be considered as even potentially dangerous to the economic interests of man. Almost similarly neutral, or of negligible importance, are most of the other Orthoptera eaten by the mongoose. One of the tree crickets of St. Croix, *Ablona guadeloupensis* (Karny), as A. B. Gurney states this Lesser Antillean species of *Gryllacris* must now be called, is indeed so inconspicuous and hard to catch as never to have been collected there before Seaman found one wrapped in a curled-up grapefruit leaf. He thought it probably responsible for damage to young fruit trees, attacking tender shoots and leaves. Other tree crickets, the cave crickets, and the common ground crickets may also at times be minor pests, but in no case did the mongoose eat such a major pest in Puerto Rico as the changa.

The cockroaches consumed by the mongoose were not the species common in houses, but wild species hardly affecting the interests of man in any way. The very decided preference of the mongoose for Orthoptera, to the exclusion of practically all other insects (if one eliminates those ants and flies

which were eating the fish bait, and those which had been previously caught and swallowed by the lizards the mongoose ate), seems most remarkable, and is as definite as that of any systematic entomologist interested in only his own group of insects. But it is not unique for the West Indies, as C. E. Pemberton (7) in Hawaii lists "crickets, grasshoppers, the locustid *Conocephalus saltator*, the grasshopper, *Oxya chinensis*" first, subsequently mentioning spiders, caterpillars, beetles, bees and wasps, with no indication of comparative abundance.

The names of small ants are as conspicuous in the list of food items as those of the largest grasshopper, yet by actual bulk and mass, thousands of ants are required to equal one grasshopper. All the Orthoptera: Cockroaches, grasshoppers, katydids and crickets, are comparatively large insects, and in St. Croix they constituted such a large fraction of the insect food that the presence of an occasional ant or small fly in reality contributed little or nothing to the nourishment of the mongoose.

Numerous other large insects occur in Puerto Rico, often in such abundance as to consitute definite pests, and all presumably available to the mongoose to catch and eat if it so desires. Yet the preponderance of Orthoptera in the food preferences of the mongoose in Puerto Rico is almost as marked as in St. Croix. To be sure, a few maybeetles, *Phyllophaga portoricensis* Smyth, and a few leaf weevils, *Diaprepes abbreviatus* Linnaeus, were found in the stomachs examined, and these beetles may actually have been caught by the mongoose, and not first eaten by lizards. If so, they are the only items in its food which can with assurance be considered as pests, as contrasted with the much greater number of beneficial lizards, and the centipedes, tarantulas, and orthopterous insects with a status neutral or undetermined. Thus, in any realistic appraisal of the food habits of the mongoose in St. Croix and Puerto Rico, it must be considered definitely deterimental, or certainly of negligible value in the control of any major insect pests.

SUMMARY

Riki-tiki-tavi, an Indian mongoose, was a hero in Rudyard Kipling's "Jungle Book" because he killed cobras and other poisonous snakes. Brought to West Indian islands such as St. Croix, where there are no snakes, or very few as in Puerto Rico, the mongoose, attacking the nearest local counterpart to snakes, primarily feeds on lizards. Lizards are insectivorous and considered largely beneficial. Indeed, most of the insect pests found in the stomach contents of the mongoose presumably were originally caught by lizards. The insects eaten by the mongoose are practically all Orthoptera: Grasshoppers, katydids, crickets, and cockroaches. Of other Arthropods, it eats mostly large spiders or tarantulas, and centipedes.

RESUMEN

Riki-tiki-tavi, una mangosta de la India, fué el héroe en el "Libro de la Selva" de Rudyard Kipling, por su habilidad para matar cobras y otras serpientes venenosas. Traída a las Antillas donde no hay serpientes, como sucede en Santa Cruz, o muy pocas como en Puerto Rico, la mangosta se dedicó a atacar lo más que se le parecía a una culebra, principalmente lagartijas.

Las lagartijas son insectívoras y por lo tanto se consideran beneficiosas a la agricultura. De hecho, la mayor parte de los insectos dañinos que se encontró en los estómagos de las mangostas observadas, con toda probabilidad fueron originalmente atrapados por lagartijas.

Los insectos que come la mangosta en su mayoría son ortópteros, tales como saltamontes, grillos y cucarachas. También come tarántulas y ciempiés.

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Erratum

Jr. of Agric. Univ. of P. R. 36: (3) 1952, page 278, 2nd paragraph, word on line 9 should be "structure" instead of "texture."